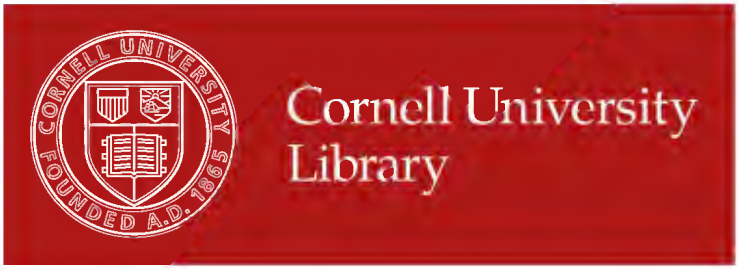

[AMERICAN INSTITUTE OF MINING ENGINEERS.]

PETROLEUM AND NATURAL GAS IN NEW YORK.

By C. A. Ashburner, Pittsburgh, Pa.

ERRATA.

In the preliminary edition, issued "subject to revision," of the above paper of the Duluth meeting, the following errors have been discovered, and corrected in the sheets of Vol. XVI of the *Transactions.*

Page 6, 27th line, Marysville should be Murrysville.

Page 10, 7th line, minimum should be maximum.

The record of the well drilled at Ithaca, Tompkins Co., given on page 36, is correct as to the successive depths of boring and also as to the several intervals (except an obvious typographical error, by which the Lower Helderberg limestones, No. 8, are made 15 feet instead of 115 feet thick); but the final column, giving the depths as referred to tide-level, is entirely erroneous after No. 5. The figures in this column should read as follows:

4	—1,216	15	—1,992
5	—1,298	16	—2,013
6	—1,376	17	—2,080
7	—1,389	18	—2,122
8	—1,504	19	—2,146
9	—1,848	20	—2,194
10	—1,872	21	—2,276
11	—1,878	22	—2,318
12	—1,932	23	—2,626
13	—1,944	24	—2,632
14	—1,961	25	—2,734

The total depth of this well, as given by Mr. Rust, the contractor, is 3,185 feet. The record stops at 3,130 feet.

In the record of the Clyde well, on page 37, under No. 6, Clinton group, "white" iron-ore should be "oölitic."

In the record of the Wolcott well, page 38, under No. 1, the words "shales below top of latter not determined" should be struck out, and the words "and shales" should be introduced after "iron-ore" under No. 2. Under No. 4 the thickness of the Gray Medina should be 210 instead of 211 feet, and under No. 8, the designation should be "Lower part of Utica Shales."

In the record of the State well at Syracuse, on page 39, the following should be substituted, from the Report of the Superintendent of the Onondaga Salt Springs, N. Y. Assembly Doc. No. 32, for 1885, page 15:

Record of State Well at Syracuse.

Salina	1. Drift 2. Red marls	555	to 555	=	—155
Salina	3. Variegated marls and limestone	23	to 578	=	—178
	4. Niagara limestone	342	to 920	=	—520
	5. Clinton shales and iron-ore	105	to 1025	=	—625
	6. Transition from Clinton to Medina	50	to 1075	=	—675
	7. Red-brown sandstone of Medina	100	to 1175	=	—775
	8. Red sandstone, alternating with gray and brown sandstones	640	to 1815	=	—1415
	9. Gray Medina or sandstone of Oswego	154	to 1969	=	—1569
	10. Bottom of well in Gray Medina at		1969		

In the record of the Seneca Falls well, on page 44, the following should be substituted:

3. Greenish gray marl	400	to 700	=	—315
4. Red shale, with some mottled red and green shale	250	to 950	=	—565
5. Dark blue Niagara limestone and Clinton, about	400	to 1350	=	—965
6. Medina shale and sandstones	150	to 1500	=	—1115
Total depth of well		1500 feet.		

The depth at which gas was found in the Medina sandstone, as stated in the paragraph immediately following the above record, should be 1455, instead of 1400 feet. And on page 46, line 1, the estimate of Prof. Williams as to the depth at which the Trenton limestone would be reached should be the least depth instead of the greatest.

On page 51, the last column of the well-record is incorrect. The numbers should read as follows: 956, 952, 949, 919, 896, 856, 826, 821, 801, 771, 756, 731, 700, 626, 516, 481, 416, 346, 331, 206, 171, 146, 141, —164, —174, —264, —319, —344, —494, —634, —654, —744, —764, —834, —984, —1244.

PETROLEUM AND NATURAL GAS

IN

NEW YORK STATE.

BY

CHARLES A. ASHBURNER, M.S., C.E.,

ASSISTANT, GEOLOGICAL SURVEY OF PENNSYLVANIA, AND ASSISTANT IN CHARGE OF COAL STATISTICS, U. S. GEOLOGICAL SURVEY,

PITTSBURGH, PA.

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1888.

PETROLEUM AND NATURAL GAS IN NEW YORK STATE.

BY CHARLES A. ASHBURNER, PITTSBURGH, PA.

Introduction.

The occurrence of oil- and gas-springs in the State of New York has been a fact of historical record since 1627, when the existence of the Cuba oil-spring was first recorded. The utilization of natural gas at Fredonia in 1821 attracted the attention of the public to the possibility of obtaining an illuminating gas by digging and drilling into the rocks. No active search was made, however, for oil or gas by the drilling of wells until after the discovery of commercial oil in Pennsylvania in 1859.

In 1862 a well was drilled at Bradford, McKean County, Pennsylvania, but a few miles south of the New York state line, to the depth of 200 feet, in search of the oil-sand which had been found at Titusville, Oil City, and at other points in Western Pennsylvania. Immediately subsequent to this, other wells were drilled in search of petroleum at a number of points in New York, particularly in the western part of the State. Some explorations have been made, in an unsystematic way, for oil ever since, explorers being much encouraged in their search by the development of the Allegany oil-district in 1879 and 1880. Immediately subsequent to the general utilization of natural gas in Pennsylvania in 1882 and 1883, a new interest was taken in the drilling of exploration wells, more particularly in search of gas.

The principal object of this paper is to publish a record of the explorations which have been made up to date for oil and gas in the State. I have not mentioned every well which has been drilled, but only the more important ones with which I am familiar. The record of these wells have a two-fold value, first, to the practical geologist and well-driller, to enable him to deduce conclusions as to the possibility of getting natural gas in special localities, and to aid in further explorations; and second, to the technical geologist,

in giving definite facts having a direct bearing upon the stratigraphy of the Palæozoic rocks throughout the State.

In communicating these facts to the Institute, it is not my purpose to state the conclusions, at which I have arrived, as to the possibility of getting commercial oil or gas anywhere within the State, since my professional relations with active explorations in different portions of the State prevent me from making public any of the practical conclusions at which I may have arrived. Nor is it my intention to review at length the bearing which these facts have upon the geological structure of the State, for two reasons: first, because I am at present collecting additional facts which will have a direct bearing upon such an investigation, and which might modify any suggestion as to geological structure which I might now make; and, second, because my professional engagements will not permit me to devote sufficient time to the question. Again, to publish a complete report on such a geological investigation would extend the present communication beyond the limits of a suitable paper for the *Transactions* of the Institute.

To one familiar with the large and unwarranted expenditure of money in the drilling of wells for oil and gas in the State, it is surprising that the State Geological Survey, which has done so much good work in the advancement of palæontological and geological science, has never made a practical report on the stratigraphy of the State, or published geological county maps, both of which would have proved of inestimable value to oil-, gas-, and other mineral explorers, and prevented a useless expenditure of money by the citizens of the State sufficient to pay for the cost of such a survey a thousand times over.

The history of natural-gas explorations in the State is naturally divided into two periods: first, that up to the discovery of the Allegheny oil-field in 1880; and, second, that subsequent to this date. Although the historical references to the existence of oil and gas, published prior to 1881, have no direct bearing in aiding present explorations, yet the records are so scattered, and have been so contorted from time to time by numerous publications in the local papers that it becomes important in this place to refer to them in detail.

Early References to Oil and Gas.

The first record of the existence of an oil-spring in the United States was by a French missionary, Joseph de la Roche-d'Allion, under date of July 18th, 1627, when he made mention in his diary

of visiting the Cuba oil-spring in Allegany County. The location of the spring was noted on a map published fifty years later, being designated by the words, *Fontaine de bitume.* Vanuxem, in his Report of 1837 refers to this spring, and Dr. Beck, in his Report on the Mineralogy of New York, published in 1842, describes the spring as follows: "It is a circular pool, about eighteen feet in diameter, filled nearly to its margin with foul water, and having no visible outlet. The water is coated with a thin layer of mineral oil, giving it a yellowish-brown color, but the quantity is inconsiderable. The peculiar odor, however, is perceptible for a considerable distance from the spring. The substance is collected by skimming it from the fountain and is used as an external application in various diseases. Indeed, so highly was it prized by the Indians that a mile square around the spring has been reserved for the Senecas."

The following references to the occurrence of natural-gas springs in different parts of the State are taken from Dr. Beck's report:

"A locality occurs in the town of Northeast, in the County of Dutchess where, from the bottom of a small lake, proceeds inflammable gas of considerable purity. A short distance from Amenia-ville in this County, the same gas rises from the bed of a small stream.

"In New Lebanon, County of Columbia, one or two similar springs have been observed.

"Inflammable gas is quite abundantly evolved through a boring made into the slate in the southern part of the city of Albany. The gas which issues from the Albany spring burns with a white flame tinged with red; and at length, when the flow of gas is temporarily impeded, the flame is of a blue color, owing probably to the imperfect combustion.

"Carburetted hydrogen gas issues through a crag or gravelly soil about a mile west of the village of Vernon, in Oneida County. According to Prof. Eaton, who made several trials in July, 1823, it issues through a spring of water at the rate of a gallon in a minute. He states that he observed it 'issuing from several small masses of water along the foot of the same hill; which naturally induced a belief that it rises from the earth in all parts of several acres of ground adjoining the chief spring.'

"Gas is evolved in considerable abundance in various parts of Ontario County. The most noted locality is in the town of Bristol, about nine miles west-southwest from Canandaigua, where it issues in a ravine on the west side of the valley of Mud creek.

"Dr. Hayes, from experiments which he made upon this gas, arrived at the conclusion that it consists principally of the light and heavy carburetted hydrogen; and that it contains carbonic acid but no sulphuretted hydrogen.

"At Cheshire, five miles east of the preceding, there are several places from which jets of this gas issue from clefts in the rock. It is observed, however, in much the largest quantities, according to Mr. Hall, in Manchester, on the east side of Canandaigua lake, its occurrence being manifested for a considerable distance along the same range.

"In Yates County, a mile or a mile and a half from Rushville, in the town of Middlesex, Dr. Hayes, in the paper already quoted, states that on the southeastern side of a valley called Federal Hollow, there are numerous jets of this gas. 'In a field near the northern extremity of this tract, and at an elevation of forty or fifty feet from the bottom of the valley, several hillocks may be seen of a few inches in height, and from two or three to ten or twelve feet in diameter. They consist of a black mould and are destitute of vegetation; from these gas issues, and on digging into the earth beneath it may be obtained in considerable streams. These hillocks have appeared successively, within a period of seven or eight years, although the ground has been cleared much longer. The first indication of their formation is the disappearance of vegetation at a particular point; this is enlarged, the mould accumulates, and the hillock is gradually formed. In very cold weather the gas is said to issue from the tops of hollow cylinders of ice, sometimes two or three feet in height, forming when lighted in a still evening a beautiful illumination.'

"In Monroe County, in the town of Riga, inflammable gas rises from a spring in sufficient quantities to supply a constant flame from a half-inch tube.

"In the town of Royalton, Niagara County, six and a half miles east of Lockport, carburetted hydrogen issues through the water of a basin on the south side of the Erie canal. This is said by Prof. Eaton not to have been observed until the water was let into the canal. Upon testing this gas, it was found to resemble that at Vernon, but it approached nearer to the character of light carburetted hydrogen. The quantity which issued through the basin at one place exceeded a gallon a minute. This place was named Gasport.

"At Van Buren Harbor, on Lake Erie, four miles from Fre-

donia, bubbles of inflammable gas may be seen rising through the water when the lake is calm, a rod or two from the shore.

"In the town of Sheridan, six and a half miles from Fredonia, the same gas is abundantly evolved in various places. And again, on the west branch of Canadawa creek, four miles southeast of that village, the carburetted hydrogen rises in considerable quantity through a spring of pure water in a marsh. This gas, when collected and forced through a small orifice, burns with a bluish-white flame.

"In Cattaraugus County, Mr. Hall states that carburetted hydrogen gas escapes from almost all the waters, whether stagnant or otherwise. It is evolved in small quantities at the oil-spring at Freedom, but it will not sustain a constant flame.

"To this account it may be added that carburetted hydrogen rises through several brine-springs, as at Clyde in Wayne County; in the valley of Elk creek, three and a half miles from the village of Delhi, Delaware County, and at La Grange, in Steuben County."

General Geological Considerations.

All of the natural gas which has been found in the State comes from some of the porous strata belonging to the Palæozoic system, with the exception of a small amount of gas which is contained in the porous sand-beds of the glacial drift. The detailed facts which are given in this communication, for each locality where any considerable amount of gas has been obtained, or where systematic explorations have been made for it, show from what strata of the Palæozoic system the gas is derived. In order, however, to give a comprehensive view of the succession and thickness of the rocks of the Palæozoic system throughout the gas-producing areas of Ohio, Pennsylvania, and New York, I have grouped on the accompanying chart a number of general sections of these strata. The thicknesses given for the different formations show wide differences, and in themselves are sufficient proof of the necessity of geological knowledge in any drilling operation, either in search for oil or gas, or in the practical development of districts where either oil or gas or both are known to exist.

In all explorations it is important to know in what geological formation drilling is commenced, and how far above the lower limit of the formation the well is started. It is no less important to know the thicknesses of the different groups of rocks through which the drill is passing, in order to make an estimate as to the proper

depth to drill to reach any definite horizon in which the existence of oil or gas can be expected. From an inspection of the accompanying chart it will be seen that the absolute thickness of any one series of strata has not been uniformly determined throughout the series of sections. This is due to the fact that it is impossible in some localities to determine the exact position of both the top and bottom of special formations. There are, however, in this section, certain geological horizons whose positions have been determined in each section, for instance, the thickness of the strata included between the bottom of the Catskill sandstone, No. IX., and the top of the Upper Helderberg limestone at the bottom of No. VIII. extends uniformly throughout the entire series. In the Catskill region in New York, the thickness of this series is 4420 feet; in the eastern part of the anthracite coal-fields in Pennsylvania it is only 3140 feet; along the Susquehanna River in Clinton County, Pennsylvania, 2440 feet, and in Huntingdon County, Pennsylvania, the strata attain their maximum thickness (in the three States for which the sections are given) of 5135 feet. In central New York they are 3912 feet thick; in western New York, 3500 feet, and in southern Crawford County, Pennsylvania, 3000 feet. In the upper part of these series of rocks occur the oil- and gas-sands of northern Pennsylvania and southwestern New York. A still wider variation in the range of thickness is shown in the Catskill sandstone, No. IX. This formation is interesting on account of its being geologically equivalent to the Venango-Butler group of rocks which contain all the oil- and gas-sands in western Pennsylvania, around Pittsburgh; in this region the Marysville gas-sand forms the top of the group and the Butler fourth oil-sand forms the bottom of the group. In the vicinity of Pittsburgh the vertical thickness of this group is 500 feet. In the Bradford oil district, Pennsylvania, and in the Allegany oil-district, New York, it is only 250 feet, while in Clinton County, Pennsylvania, it is 2100 feet and in Huntingdon County, 2680 feet; along the Lehigh River, in Luzerne County, the group attains its maximum thickness of 7145 feet. In the Catskill Mountain region, New York, from which this group takes its name, the thickness is only 2900 feet. Another notable variation in the thickness of the same rocks exhibited by the accompanying chart, is in the thickness of the Devonian and Silurian strata in central Pennsylvania and central New York. In central New York these strata are 9000 feet, and in central Pennsylvania 22,000 feet thick.

NOTE.—In the 27th line of this page, "Marysville" should be "Murrysville."

Geological Map of New York.

The accompanying geological map of southern and central New York and northern Pennsylvania, I have compiled from the maps of the Geological Survey of Pennsylvania, from my own field-explorations* in the State of New York, and from scattered records of Professor James Hall and other New York geologists. See Plate I.

The map is especially interesting to oil- and gas-explorers, when studied in conjunction with the sections given on the accompanying chart, and the detailed sections given in the description of local explorations. The most interesting fact, which is best brought out by this map, is that the Catskill Red sandstone, No. IX., which represents the Venango oil and gas-sand group of Pennsylvania, outcrops in northern Pennsylvania and southern New York, and that it is therefore impossible to hope to get oil or gas in northern Pennsylvania and southern New York in the same geological horizon from which the oil and gas in the vicinity of Pittsburgh is obtained.

Conditions Attending the Occurrence of Natural Gas.

Although it is impracticable, as I have stated, for me at the present time to publish the conclusions at which I have arrived as to the possibility of gas occurring in commercial quantity in different sections of New York, yet a brief reference to the general conditions controlling the existence of natural gas will be of special interest, in conjunction with the detailed facts contained in this paper.

At the time of the formation of the sand and limestone beds in which natural gas is now found, there were undoubtedly buried some of the organic remains from which both oil and gas were subsequently formed; but I believe that a large part of both the oil and gas has come from the organic remains buried in the associated strata, and that the porous beds in which they are now found merely act as reservoirs to hold them. There is no question but that the largest deposits of natural gas will be found in regions in the vicinity of which petroleum is found. Although the geological and physical conditions under which natural gas has been obtained in commercial quantities vary to a considerable extent in different localities, yet the most important conditions attending its occurrence may be enumerated as follows:

* The most extended explorations which I have made in New York have been in the Mohawk valley, in the Catskill Mountain region, and from thence southwest to Pennsylvania, and in the southern part of western New York.

First. The original extent of vegetable and animal life at the time of the deposition of the sedimentary strata in which these remains were buried or of which they were formed.

Second. The existence, in close proximity to the strata containing such organic remains, of a porous and more or less homogeneous sandstone or shale, or a porous and cavernous limestone included in the rocks. Such porous strata serve as reservoirs to hold the gas resulting from the decomposition of the organic remains referred to. In many cases, the rocks in which a large amount of the organic remains were buried serve also as a reservoir to hold the gas.

Third. Solid strata, undisturbed by cracks and crevices, overlying the gas-reservoir rocks to prevent the escape of the confined gas into the atmosphere. In cases where the gas contained in the reservoir-rock has come from the organic remains buried below the reservoir, it is necessary that there should be cracks in the underlying rocks in order to permit the gas to flow into the reservoir.

Fourth. A moderate dip of the strata (the most favorable dip for the occurrence of gas being at the rate per mile of less than 75 feet), and the position of the anticlinals or saddles, and synclinals or basins in the strata associated with the gas-reservoir rocks.

Fifth. The relative proportion of water, oil, and gas contained in the gas-reservoir rock.

Sixth. The pressure under which the gas exists before being tapped by wells; this pressure is now generally called the rock-pressure, to distinguish it from the flow-pressure, or the pressure under which the gas flows from the wells.

A popular impression exists that the only rocks in our geological scale which contain carbonaceous remains are those of the Carboniferous age. This impression is probably due largely to the fact that this name has been assigned to the formation which contains the largest coal-deposits in Great Britain, in the central and eastern parts of the United States, and elsewhere.

In the geological ages prior to the Carboniferous, there did not exist sufficient land-vegetation to form extensive coal-beds; but the fossil remains of water-plants amply attest the fact that there was buried in the rocks below the Carboniferous a great abundance of vegetable forms. Even in the Laurentian rocks of Canada, far below where I believe it is possible to find natural gas, there is a large accumulation of carbonaceous material in the form of graphite, which is now universally conceded to have been derived from the remains of vegetation. These plants belonged to the lower forms of

vegetable life, as the animal remains of which many of our limestones are composed belonged to the lower forms of animal life. The latter, no doubt, are the source of the large amount of both oil and gas derived from the limestone beds. According to researches made by Professor Peckham, in southern California, the petroleum and gas there are probably derived from microscopic animals.

No less important to the existence of gas or oil is the occurrence of a porous rock, to act as a reservoir, to hold the hydrocarbon products formed by the distillation of the organic remains. In the case of the oil and gas of Pennsylvania, a porous sandstone or sandy shale always acts as the reservoir-rock. This is also the case in the Allegany district, in New York, and in eastern Ohio. In western Ohio, Indiana, and Kentucky, the reservoir-rock is invariably a porous and cavernous limestone. Professor Orton claims that the porosity of the gas-producing limestone in Ohio "is due to the interlocking of its crystalline growths." This may, in a small degree, account for the porosity of the rock; but, from my examination of the pieces of the gas-rock brought up from producing gas-wells at Findlay, and of the limestone from other wells, and also of the Trenton limestone along its outcrops in Pennsylvania and New York, I believe that the porosity of the limestone is due almost entirely to small cavities which have been excavated in the rock by percolating waters. These cavities, in some places, are extremely minute.

The relative capacity of the pores of the Trenton limestone to the bulk of the rock itself has never yet been fairly determined for any oil or gas-producing district deriving its product from a limestone bed. Mr. Carll has estimated that a good productive oil- and gas-sand in the Venango group can hold one-tenth of its bulk of oil: assuming that the oil-sand was only 15 feet thick in the most productive portion, it would contain, on an average, 9,600,000 barrels of oil per square mile. From my own estimates, I have determined that the oil-producing sand in the Venango district, up to the present time, has only produced an average of 900,000 barrels of oil per square mile. It is impossible to determine the absolute thickness of the reservoir-sand over any definite area, even as small as that ot one square mile. There are so many variable factors which enter into the problem that it is difficult to arrive at any fair conclusion on the question of relative porosity. From estimates which I have made of the producing capacity of the oil- and gas-sands of the different Pennsylvania and New York districts, I believe that the amount of oil which will be ultimately retained, by

capillary attraction, in the pores of the sand-beds, will range from eight to nine times as much as the total amount of oil which it will be possible to extract from these sand-beds through wells.

The existence of a solid impervious rock-roof over the gas-reservoir rock is necessary to the retention of the gas in the rock. Experience so far goes to prove that very few gas-wells have been obtained with a minimum daily capacity of a million cubic feet of gas in territories where the wells are less than 400 feet deep; whereas, some of the largest gas-wells have got gas from reservoir-rocks with only 800 to 1000 feet of covering.

That the absence of both petroleum and natural gas in plicated strata in Pennsylvania, east of the Allegheny Mountain crest, is to be explained by the cracking of the rocks, is evident, since the survey of the outcropping rocks, and a study of the records of dry wells, show that the oil- and gas-sands extend far beyond the limits of the area of the region in which any traces of oil or gas have ever been found. Even within the area where oil- and gas-wells have been found, the cracking or jointing of the rocks must have a potent influence upon the amount of oil or gas obtained in certain localities. From surveys which I have made in Elk County, Pennsylvania, it appears that the direction of certain streams is to be attributed to their flow along joints in the rocks, which have resulted from the contraction of the earth's crust during the process of secular cooling. I believe that this, in a measure, accounts for the occurrence of gas at certain points in western Elk County, and its absence at other points, the gas being obtained where the rocks are not jointed, and not being found where they are jointed.

The tendency of natural gas, petroleum, and water—which are invariably associated, to some extent, in all oil- and gas districts—to separate according to their respective specific gravities, makes it essential that the dip of the reservoir-rock and the position of anticlinals and synclinals shall be taken into consideration in locating oil- and gas-pools and oil- and gas-wells. If the reservoir-rock were uniformly porous and homogeneous over the arch of the anticlinal, the crown of the latter being level, and its cross-sections, transverse to its axis, being entirely similar throughout its extent, the best gas-producing territory would, of course, always be found on the crest of the anticlinal, immediately over the anticlinal axis, and the so-called *anticlinal theory* would always be a safe and unvarying guide for the location of a gas-pool. Such conditions are never universal in any oil or gas-district with which I am

NOTE.—In the 7th line of this page, "minimum" should be "maximum."

familiar: there exist in all gas-pools many modifying and purely local conditions which must enter into the consideration of the best localities in which to drill a well either for oil or gas. It is impossible, in this connection, to treat this subject at length, but I will mention two important modifying conditions: If an area underlaid by porous rock be of limited extent along an anticlinal axis, but of greater extent across an anticlinal and its adjoining synclinals, and if the pores of the rock be filled almost entirely by natural gas, the natural gas will, of course, be found in any well which may be drilled into the porous rock under this area, irrespective of the relative position of the well to the anticlinal axis or to the synclinals. Again, if the crest of the anticlinal, instead of being horizontal, dip along its axis, and the porous rock passes over the anticlinal and its adjoining synclinals on either side, a gas-well might be obtained in the center of either synclinal if the elevation of the porous rock in the center of the synclinal be higher than the elevation of a point in the porous rock on the crest of the anticlinal. For instance, if a gas-well be found on the crest of an anticlinal at any point, and the dip into the center of an adjoining synclinal one thousand feet from the anticlinal axis be twenty feet, and the dip along the crest of the anticlinal in a distance of five thousand feet be fifty feet, the chances for getting a gas-well at the point indicated in the synclinal are much greater than the chances of getting a gas-well on the crest of the anticlinal, five thousand feet distant from the producing well.

Where the rocks have a minimum dip they have necessarily been least disturbed since the time of their deposition, and in these localities we find the cover to the gas-sand less broken by cracks than in other localities where the dips are greater and the synclinals and anticlinals more defined.

The relative proportion of water, oil, and gas, and the pressure under which they exist in the reservoir-rocks, must, of course, affect the amount of gas which can be obtained in any given time from a well, and also the duration of the well. This is too great a subject to be fully treated in this place; but it may be sufficient to state that the amount of gas which can be commanded per day from a given gas-territory, and the duration of the gas in the large gas-districts, such as that surrounding Pittsburgh, and in Warren County, Pa., and in the Findlay district, Ohio, will certainly be as great as has been claimed by Professors Lesley, Carll, Orton and myself, who have given this subject the most careful consideration. That

the bulk of the gas which can be obtained for commercial purposes now exists and is stored up in inexhaustible reservoirs, I have no doubt; still, at the same time, there is a slow accretion to the supply constantly going on, which is a product of the continuing distillation of carbonaceous matter contained in the rocks. This product is so small, however, that it can hardly enter into the consideration of the question from a commercial standpoint.

Popular Plans of Explorations.

About a year ago extensive operations for the exploration of natural gas were planned by a gas-company, organized for the purpose, in northeastern Pennsylvania and southeastern New York. The plans and operations of this company fairly illustrate the unsystematic plan pursued by similar organizations in many localities in the United States, and are worthy of note. As far as I can gather, the plans of this company have been based upon information gathered from various sources.

In the first place, it was currently reported that a Pennsylvania geologist had succeeded several years ago in tracing the oil- and gas-sands of the Venango group in Western Pennsylvania east as far as Susquehanna, Wayne, and Pike counties in northeastern Pennsylvania. Whether this report was founded upon any statement made by a geologist or not, the fact is that although the geological horizon of the Venango oil- and gas-sands does exist under Susquehanna, Wayne, and Pike Counties, yet the sands themselves have thinned out and do not exist east of McKean County, which is 110 miles west of Susquehanna County.

In the second place, certain gas-springs were found to exist in the Delaware valley, principally in the vicinity of Port Jarvis, which naturally emphasized the report in regard to the Venango oil- and gas-sands. That these springs are in themselves any indication of the existence of natural gas in commercial quantities, our experience does not bear out.

The results of the drilling operations of the company, as far as they have been reported to the public, are of interest as showing where natural gas does not exist in commercial quantities, but judging from the location of the wells and the character of the strata drilled through, they certainly throw no light on the question as to where possible gas-pools may exist in the vicinity of the wells which have already been drilled.

The fact that the managers of this company are reported to com-

prise experienced operators in the oil-fields and Philadelphia capitalists, and that they will drill other wells until their territories of 50,000 acres, more or less, shall have been thoroughly explored, fails to inspire confidence in the enterprise. I question their wisdom in adopting a policy, the motive of which seems to be to determine by costly drilling the territory which does not contain gas, rather than to determine by a judicious, systematic, and intelligent method whether any gas-pools exist under their properties which contain gas in commercial quantities and at points where it can be commercially utilized. If I am correctly informed of the location of this territory, a careful systematic drilling of two or three wells under the direction of an engineer and geologist experienced in the occurrence of natural gas, for the entire property, with a small expenditure of money, would no doubt settle the question of the existence of natural gas in commercial quantity; whereas it is currently reported that the company had expended, up to December, 1887, between $40,000 and $50,000 in drilling wells without having arrived at any practical conclusion as to whether it is *possible* for any gas to exist under its territory.

The Fredonia Gas-Wells.

The earliest published reference to natural gas in the State of New York was to the gas-springs near the village of Fredonia, on Canadaway Creek, in Chatauqua County, about three miles south of the Lake shore. Gas was first utilized here about 1821. Dr. Beck, in speaking of these springs in 1842, says: "The gas-springs seem to have their origin in the strata of slate which form the bed of the stream, and which are everywhere met with in this vicinity, a short distance from the surface of the earth." At one point where more than the usual discharge of gas was observed issuing from a fissure in the rock, a shaft was dug through the slate to a depth of twenty-two feet. This shaft was closed and the gas was conveyed by a pipe from the shaft to a gasometer near by, which had a capacity of 220 cubic feet and could be filled in about fifteen hours with gas sufficient to supply from 70 to 80 lights. The gas was used for illumination in an adjoining mill, in several stores, and in a hotel. The history of the Fredonia gas-district is interesting because this is the first natural gas which was profitably used.

The following is a statement contained in the History of Chatauqua County, the accuracy of which is vouched for by persons who have been associated with the Fredonia Natural Gas Company:

"The use of natural gas in Fredonia was begun in 1821, when experiments were made to determine its illuminating value, and it was introduced into a few of the public places, among which was the hotel that then occupied the site of the Taylor House, and which was illuminated when Lafayette passed through the village in 1824. The gas so used at that time was the first used in the United States, and the gasworks established here were the first in this country. The spring first discovered, and from which the gas was first used, is located on the north bank of the Canadaway Creek, at the bridge crossing the stream at Main Street, in the village of Fredonia. The gas escaped at various places in the immediate vicinity, but when the well was sunk it was all drawn to it. The gas from this well, which was sufficient for thirty burners, was used alone until 1858, when another well was sunk on the creek in the northwest part of the village, by Preston Barmore, the shaft being thirty feet deep, six feet in diameter at the top and fourteen feet at the bottom, with two vertical borings, one of 100 and the other of 150 feet depth. In the fall of 1858, Elias Forbes purchased a half interest in the well, and that fall a company was formed, and during the remainder of that and the following year the gas, in sufficient quantity to supply about 2000 cubic feet per day, was conducted to the village through three miles of mains and supplied directly from the well to the stores of the village. During the latter year (1859) the company put in a gas receiver or holder of 12,000 cubic feet capacity, and supplied private houses. In the fall of 1871 Alvah Colburn made a boring for gas near his mill, with a view to supplying fuel for generating steam therefor, but the supply was inadequate for that purpose, though it was evolved in considerable quantity. He therefore purchased the Barmore interest in the gas company and connected his well, which is 1200 feet deep, with the company's receiver. Since that the supply of gas has been ample for the demands of the village. Previous to the opening of Colburn's well the supply of gas was not sufficient to meet the demands for it during the winter, and the deficiency was made up by gas manufactured from coal. Professor Hadley's experiments show that the consumption of natural gas as compared with that manufactured from coal, through burners of equal capacity and in equal times, is less than one-half, with a greater candle power. He shows that a burner which consumed six feet of coal gas in one hour, with an illuminating power equal to fourteen sperm candles, six to the pound, consumed of the natural gas a fraction less than three feet, with an illuminating power of a

little more than sixteen sperm candles. The natural gas also possesses a greater diffusive power, and one who has been accustomed to the use of coal gas finds it difficult to read ordinary print without being in close proximity to the light, is astonished at the facility with which he can read in any part of an ordinary-sized dwelling-room under the light from the natural gas."

The Fredonia natural gas is still used extensively for illumination, the candle-power of the gas being much greater than that of the natural gas found in the vicinity of Pittsburgh. Mr. E. J. Crissey, Secretary of the Fredonia Natural Gas (Light) Company, in a private letter in 1882, says: "The gas from this well (Colburn), which was sufficient for about thirty burners, was used alone until about 1858, when another well was drilled which supplied some two hundred burners. Another well was drilled in 1871 with better success. The average monthly supply of the three combined is about 110,000 cubic feet, of which an average of 80,000 cubic feet per month is consumed for lights. Seven other wells, varying from 50 to 800 feet deep, have been made without success. The area covered by these wells is about one mile in length by one-half mile in width. The supply has not perceptibly diminished since the opening of the wells."

The report of the Fredonia Natural Gas Company shows that in 1886, in a district containing a population of 3000, the price of gas per thousand cubic feet was $2.50; 72 public lamps were supplied with gas, at an annual price of $12 each. During that year no record was made of the total annual consumption of gas.

Mr. John F. Carll reports the Fredonia gas to come from strata immediately above the Corniferous limestone. The following are the facts reported to Mr. Carll by Mr. Alvah Colburn, President of the Gas Company:

"In digging the conductor to the rock some gas appeared. After the drill was introduced the gas increased all the way down to 700 feet, below which point no further increase was obtained.

"The limestone (Corniferous) was struck at 1050 feet and continued until the drill was stopped at 1207 feet. It was 'hard and flinty,' and produced neither oil or gas. The well is tubed at 700 feet. The lower part of the hole fills up to the tubing with salt water. The pump is put in motion about once a year, but there seems to be no accumulation of water above the bottom of the tubing.

"The flow of gas is 4000 cubic feet per day by measurement. Pressure 19 pounds per square inch. The well was drilled in 1871

or 1872, and is apparently delivering as much gas now (October, 1877) as when first struck.

"Mr. Colburn kindly gave me some specimens of limestone, one of which, coming from a depth of 1200 feet, contains a well-preserved fossil shell, readily recognized as the Atrypa prisca, figured in *Geology of New York*, vol. iv, p. 175."

It is of interest to note here the character of the Corniferous limestone; and no better description can be found than that given by Professor James Hall in his report of 1843, as follows:

"The color of the Corniferous limestone varies from a light grayish-blue to a dark blue or black, and it is sometimes even of a light gray or drab color. It contains numerous nodules of hornstone, and the strata are sometimes separated by irregular layers of the same. In other localities these layers of hornstone increase in number and thickness to the almost entire exclusion of calcareous matter, and they then present a very harsh outline. At the eastern end of the district the hornstone is intermingled and interstratified with the calcareous strata, the whole very dark colored. The same character prevails at the western extremity of the district, where the rock outcropping on the Niagara has, from its black color, given name to the village of Black Rock."

The Corniferous limestone at Black Rock is 52 feet above the surface of Lake Erie, or 625 feet above tide. In the Colburn well at Fredonia, the Corniferous limestone was found in the well at a depth of 1050 feet or 315 feet below ocean-level, the top of the well being 735 feet above ocean-level, so that the average dip of the limestone from Black Rock to Fredonia, a distance of 38 miles in a direction south, 35 degrees west, is 25 feet per mile. According to Prof. H. S. Williams, at Gowanda, in northern Cattaraugus County, about 20 miles due east of Fredonia, the Corniferous limestone is not far from 1000 feet below the surface. The upper 700 feet of this interval is composed of Portage and Genesee shales, and the lower 300 feet of Hamilton and Marcellus shales. From a comparison of the outcrops in the northern part of New York and in Canada West with the records of the Wyoming County salt-wells, Prof. Williams concludes that the Helderberg and Salina formations together range from 450 to 500 feet thick, or including the Corniferous limestone the thickness would be 600 feet. From this he concludes that the salt horizon of Wyoming County should be struck below Gowanda at 1600 feet. He further estimates, from his examination along the Niagara river, that the aggregate thickness of the Niagara,

Clinton, Medina, Hudson River and Utica formations is not less than 1500 feet, making the Trenton limestone at least 3100 feet below the surface at Gowanda. From these facts the following would be an approximate section of western New York in the vicinity of Gowanda:

Portage and Genesee,	700 feet
Hamilton and Marcellus,	300 "
Corniferous,	100 "
Lower Helderberg and Salina,	500 "
Niagara, Clinton, Medina, Hudson River and Utica,	1500 "
Total,	3100 feet.

Composition of Fredonia Gas.

A number of analyses have been made of the Fredonia gas. In 1886, a French geologist, M. Foucou, collected a sample of the gas which was analyzed by M. Fonqué and reported to be a mixture of marsh gas (CH_4), ethyl hydride (C_2H_6), with a small quantity of carbonic acid and 1.55 per cent. of nitrogen. In 1887, Professor Francis C. Phillips made an analysis of the Fredonia gas for the Geological Survey of Pennsylvania, with the following results:

The sample of gas analyzed was taken from the mains of the Fredonia Natural Gas Light Company, May 12th, 1887.

Two determinations of nitrogen in this gas gave 9.58 per cent. and 9.50 per cent. respectively. Mean, 9.54 per cent.

In two determinations of carbon dioxide there were found 0.38 per cent and 0.44 per cent. Mean, 0.41 per cent.

Results of Analysis of Fredonia Gas.

Nitrogen,	9.54 per cent.
Carbon dioxide,	0.41 " "
Olefines,	none.
Carbon monoxide,	"
Free hydrogen,	"
Ammonia,	"
Hydrocarbons of the paraffin series,	90.05 per cent.
	100.00 per cent.

343.47 cubic centimeters of Fredonia gas yield on combustion:

H_2O — 0.6254 gm., corresponding to H — 0.06964 gm. = 21.83 per cent.
CO_2 — 0.9144 gm., corresponding to C — 0.24938 gm. = 78.17 per cent.
100.00

Making allowance for the 9.95 per cent. of nitrogen and carbon dioxide contained in the gas, it is calculated that the 90.05 per cent. paraffins present contain:

Per liter — 0.80627 gm. carbon.
0.22515 gm. hydrogen.

In a second combustion of Fredonia gas, 326.17 cubic centimeters yielded:

H_2O — 0.5927 gm., corresponding to H — 0.0660 = 21.89 per cent.
CO_2 — 0.8635 gm., corresponding to C — 0.2355 = 78.11 per cent.
100.00

As these quantities of carbon and hydrogen belong exclusively to the paraffins in the gas, it is calculated that the paraffins—amounting to 90.05 per cent. of the total gas—will contain:

Per liter — 0.80185 gm. carbon.
0.2247 gm. hydrogen.

In these calculations an allowance is made in the determination of the carbon for the very small quantity of carbon dioxide which always occurs in the original gas.

The means of the two results above cited are, per liter of paraffins:

0.80406 gm. carbon, ... = 78.14 per cent.
0.22492 gm. hydrogen, ... = 21.86 per cent.
100.00

In the above case, no tests were made at the wells. A test made at one of the wells in August, 1884, showed traces of oxygen. In the limited quantity at disposal for the above analysis, no positively certain indication for oxygen could be obtained.

Williams's Conclusions for Western New York.

Professor H. S. Williams, whose conclusions as to the section of these strata have been quoted above, says:

"The character of the rocks, as far as known, would indicate that more or less gas would be found for the first seven or eight hundred feet down. This is the place in the series for the Devonian black shales, and as far eastward and northward as Livingston and Genesee counties whenever they come to the surface the shales are strongly

permeated with petroleum odor. But above the black shales the first coarse sandstones in the above-named counties, and in Wyoming County are always strongly scented with petroleum when freshly taken from the quarry.

"Also there are frequent gas-springs, dotted all over the southwestern part of the state, and occasionally oil-springs, the source of both the oil and gas of which is doubtless these black shales.

"In Western New York, although there are slight low folds, the whole inclination of the rocks is southward, and there is no reversal of the dip to form an anticlinal or large dome until the limits of the state are reached.

"From these facts it results that if there were gas originally formed in the Trenton, under Western New York, there is nothing in the geological structure to suggest that any considerable reservoir of gas is there at the present time. Such are the indications from the study of the surface-rocks of the region.

"In the southern part of Cattaraugus County, both from the higher elevation of the surface and by the gradual dipping under of the strata, the black shales, with the capping sandstones (Portage or other layers in the Chemung), are low enough to be reservoirs of oil and in some cases also yield gas."

The Buffalo Gas-Wells.

The Buffalo Cement Company has drilled, since 1883, four wells in order to test the presence of natural gas, salt-water or salt-rock or other valuable minerals under its property, consisting of about four hundred acres of land, situated wholly within the city limits. A number of valuable facts relating to these explorations have been communicated to me by Mr. L. J. Bennett, President of the company.

Well No. 1 was drilled in 1883 with a diamond drill. A complete core of the rocks passed through is now in the possession of the company, but will ultimately be deposited in the Museum of the Buffalo Society of Natural Sciences. This well showed gas in a very limited quantity at a depth of 451 feet, 9 inches, which slightly increased in volume down to 490 feet, 6 inches, where the drilling ceased. The gas-rock, as shown by the cores, is a very compact sandstone with numerous pin-point openings.

Well No. 2 was put down, in 1884, to a depth of 1305 feet, but proved unsatisfactory. No salt was found and but little salt water; and no perceptible increase of gas was obtained beyond that shown

in well No. 1. Mr. Bennett writes that from the best information based upon his drill-notes, the various rocks penetrated in well No. 2 were as follows:

Lower Helderberg limestone,	50 feet.
Salina shales,	550 "
Niagara limestone and shales, Clinton sandstone and shale,	185 "
Medina sandstone,	520 "
Total,	1305 feet.

This well and No. 3 were drilled with a $5\frac{5}{8}$-inch jump-drill.

In May, 1887, a third well was drilled in which more gas was obtained than in either of the previous wells. The gas-rock, at a depth of about 460 feet, was shot with a 40-quart torpedo of nitro-glycerine, after which the amount of gas sensibly increased. The gas was shut in the well and a steam-gauge attached to the casing, which indicated a pressure of 60 pounds per square inch in 15 minutes, and 142 pounds per square inch as the maximum confined pressure. In December, 1887, six months after the completion of the well, a meter-test was made of the amount of gas discharged at the end of an inch and a quarter pipe, 865 feet from the well, and it was found to be 27,600 cubic feet per 24 hours. The gas is reported strongly impregnated with sulphur, but gives satisfactory results as a fuel. This well is 517 feet deep, having passed through 50 feet of Lower Helderberg limestone and 467 feet of Salina shales. Mr. Bennett reports that the company is now drilling well No. 4, and has under contract a fifth well, with the hope of obtaining more gas than in the first three wells. It is also proposed to drill No. 2 deeper, until the Trenton limestone is encountered. As far as I am aware, however, no reliable estimate has been made by an experienced geologist as to the depth to which this well would have to be drilled before reaching the Trenton limestone.

Dr. Julius Pohlman, Director of the Museum of the Buffalo Society of Natural Sciences, has made a careful study of the strata passed through in wells Nos. 1 and 2. Referring to well No. 2, he says:

"Beginning at a spot where the rocks of the water-lime group, suitable for the manufacture of cement, had been removed, and which is 70 feet above the level of Lake Erie, or 643 feet above tide-water, the drill encountered the following strata:

1–25 feet, shale and cement rock in thin streaks;
25–30 feet, tolerably pure cement rock;
30–43 feet, shale and cement rock in thin streaks;
43–47 feet, pure white gypsum;
47–49 feet, shale;
49–61 feet, white gypsum;
61–62 feet, shale;
62–66 feet, white gypsum;
66–73 feet, shale and gypsum, mottled;
73–131 feet, drab-colored shale with several layers of white gypsum, measuring 18 feet in all;
131–133 feet, dark-colored limestone;
133–137 feet, shale and limestone;
137–140 feet, dark-colored compact shale;
140–720 feet, gypsum and shale, mottled and in streaks;
720–725 feet, limestone;
725–760 feet, soft red shale;
760–785 feet, white solid quartzose sandstone, very hard;
785–1305 feet, soft red shale.

"At 1305 feet the drill was stopped. Permanent water was struck at 43 feet; gas of fair quality as well as quantity, at 452 feet; salt water, leaving on evaporation about 12 per cent. of salt, was found at 555 feet. A shaft, 20 feet square, was sunk on the premises later, for the purpose of determining the feasibility of mining the gypsum, but the rush of water through the gypsum layer at 43–47 feet, was so strong that a pump with a capacity of 2000 gallons per minute failed to make any impression upon it, and the attempt was abandoned.

"The average dip of the rocks from the north to the south, in this vicinity, is about 20 feet to the mile. The top of the Niagara limestone, ten miles north of Buffalo Plains, is about 20 feet above the level of Lake Erie, or 593 feet above tidewater; hence, as the drill started at 70 feet above the lake level, Niagara limestone ought to be found at a depth of about 250 feet; but in fact, the drill penetrated down to 1305 feet in the soft red shale, characteristic of the lower part of the Onondaga Salt Group, according to Hall, demonstrating that the Niagara limestone, if present, has between Niagara Falls and Buffalo, a dip of at least 130 feet to the mile."

Dr. Pohlman's opinion that the drill in this well did not penetrate below the Salina measures, and that the dip of the Niagara limestone between Niagara Falls and Buffalo is at the rate of 120 feet

to the mile, has been questioned by a number of local geologists. As I have made no personal investigation on the ground of these two questions, I am not prepared to express a professional opinion.

Oil and Gas in Allegany County.

No geological report has ever been published on the oil- and gas-sands of the Allegany district; in fact, no careful survey has ever been made of its geology. All the geological information which is available is that which has been gathered during the progress of private surveys made by Mr. John F. Carll and myself. I have made a number of examinations in the district during the past twelve years, and have sufficient data in my possession to arrive at definite conclusions as to the details of the geological structure. It is impossible in this place to give all of my facts or to make a complete descriptive geological report, but a few facts given here will be of special value for a clear general understanding of the geology, not only of the oil- and gas-district, but of Allegany County. Before giving these facts, I desire will state two conclusions at which I arrived over five years ago and which makes clear the connection between the geology of this district and that of the Bradford oil-district in McKean County.

1. The geological horizon of the Allegany oil- and gas-sand which is commonly and locally known as the Richburgh is the same as that of the main producing oil- and gas-sands of the Bradford region, known by the oil-well drillers as the Bradford third sand, although it has no direct structural connection with the Oil Creek third sand, which is more generally known simply as the "Third Sand" and which occurs, geologically, 1000 feet above it. The Bradford oil-sand at the city of Bradford lies 1030 feet below sea-level; the elevation of the top of the sand above sea-level being 414 feet.

2. The oil-sand struck in the old Waugh and Porter well No. 1 on lot 34, Bolivar township, at a depth of 1330 feet, is undoubtedly the same as the Bradford oil-sand, and consequently the same as the Richburgh sand.

These two conclusions are not only of interest to the geologist but of great practical value to the oil- and gas-operator. The position which has been generally assigned to the Allegany or Richburgh oil- and gas-sand in the geological column is about 300 feet above the Bradford sand. This conclusion of the well-drillers and a number of local geologists has been based upon the fact that the lithological characteristics of the strata above the producing sand in

the Allegany district and in the Bradford district are different. The sandy measures in the 1000 or 1500 feet immediately overlying the oil-sand of Bradford and Allegany are poor guides in looking for oil and gas-sands in new or wild-cat territory around either the Allegany or Bradford oil- and gas-districts. They lead to confusion, error and disappointment. It is true that in a limited territory within the Bradford district there are distinct sands 300 and 600 feet respectively above the Bradford oil- and gas-sand, but I am quite confident that it is impossible to determine the position of the main producing oil- and gas-sand by the location of these upper sands. The correctness of my conclusions as to the geological relationship existing between the Bradford sand, the Allegany sand and the Waugh and Porter sand will, I think, be acknowledged after a careful study of the few facts given here.

The geographical location of the oil- and gas-wells referred to in Allegany County may be ascertained by reference to the accompanying map (Plate III).

On lot 29 in Genesee township, the top of the Richburgh- oil and gas-sand was struck in the old Cranston well No. 1 at a depth of 1704 feet; the elevation of the well being 2225 feet above tide. The same sand was struck in well No. 2 at a depth of 1709 feet; the elevation of this latter well above tide being 2235 feet. Less than a quarter of a mile southeast of well No. 1 occur detached blocks of sandstone and conglomerate from the outcrop of the Olean conglomerate. Some of these blocks range from 20 to 30 feet on a side and are 15 feet high. As nearly as could be ascertained from a careful study of these rocks, the elevation of the bottom of the Olean conglomerate, of which these rocks are the broken-down outcrop, is 2255 feet.

These facts show that the top of the oil-sand is 1729 feet below the bottom of the Olean conglomerate. The oil-sand in the Cranston wells is without doubt the same as the oil-sand which has proved so productive in the old Davis wells on lot 31, Genesee township; in the old Davis and Haldeman wells on lot 24, Genesee township, in the wells on lot 17, Clarksville township, and also in the Armour and White wells on lot 24, Genesee township. The elevation of the top of the oil-sand in the wells referred to, which is given in the accompanying table, proves conclusively that this sand is the same as the oil-sand generally productive throughout the entire Alleghany district. At Bradford the oil-sand is found 1779 feet below the bottom of the Olean conglomerate, so that the rocks composing

the interval between the oil-sand and the Olean conglomerate thin down only 50 feet toward the northeast in a distance of twenty-six miles between Bradford and Bolivar. This is less than might have been expected from an inspection of the thickening of the rocks composing this interval from Bradford south and southwest. The elevation of the oil-sand in the Waugh and Porter well is 500 feet above tide; the elevation of the bottom of the Olean conglomerate above this well is 2200 feet; so that the vertical distance between the Olean conglomerate and the Waugh and Porter sand is 1700 feet, as against 1729 feet in the western end of the Alleghany district, and 1779 feet at Bradford, thus proving conclusively that the productive sands of these three localities occupy the same geological horizon.

The principal value of this conclusion can be appreciated when it is known that a hope has always been entertained by many of the well-drillers and operators in the Allegany field, of finding a second productive oil and gas-sand in that field 300 feet below the Allegany gas-sand, and representing the Bradford oil-sand. Many thousand dollars have already been uselessly spent in drilling wells with this object. This conclusion, privately communicated for the first time to a number of operators in 1883, and published for the first time about a year ago, proves the folly of continuing this search further. It may be accepted as beyond question that the productive oil- and gas-sands in the vicinity of Richburgh, Bolivar, Allentown, the Waugh and Porter well and at Bradford are geologically the same, although they differ much in their physical characteristics.

The first well drilled in Allegany County of which I have any record was at Independence. This well was sunk in 1865 by a stock company, and a slight showing of oil and gas was obtained in a thin sandstone about 300 feet above what afterwards proved to be the Allegany oil-sand. The next well was drilled by Tadder & Company with similar results, a year or two later. In 1878, Clark & Company, of Scio, put down the third well near the second. This well was drowned out, and the fourth was drilled by Collins & Clark during the same year. All of these were located in the northwestern part of Independence township. In September, 1877, the Honeoye or Alma well, on lot No. 25, south Alma township, was commenced by the Wellsville & Alma Oil Company and finished in November. It was drilled to a depth of 1800 feet, cost $4000, and proved a failure. At a depth of 500 feet considerable gas was obtained, which ultimately took fire and burned down the derrick.

At a depth of 1000 feet, a small amount of oilwas obtained but a torpedo failed to increase the yield, and the well was finally abandoned.

The discovery of oil in commercial quantities in the Bradford district in 1874, and its active development, which commenced in the latter part of 1875, stimulated drilling in the surrounding region. Mr. O. P. Taylor, a native of Virginia, but at the time a resident of Wellsville, Allegany County, proposed to drill in the vicinity of the town in 1877. In 1878 he persuaded citizens of Wellsville to unite with him in drilling a well on lot 26, Alma township. The well failed to get oil in paying quantities, and succeeded only in proving the existence of an oil-sand. This was sufficient encouragement to the drilling, on lot 118 in the same township, of a second well, known as Pikeville No. 1, which was completed in November, 1878. The elevation of the top of this well is 1775 feet, and the top of the oil-sand was struck at a depth of 1028 feet; the oil-sand consisting of two beds 18 feet thick, separated by 7 feet of slate. Considerable gas was obtained in this well, from the top of the oil-sand down to a depth of 1091 feet. Oil was also struck, which Mr. O. P. Taylor informed me personally would have amounted to five or six barrels a day if properly pumped. This was not considered sufficient to make the well a paying and profitable one and it was abandoned.

In January, 1879, Taylor's third venture, known as the Wycoff well, was completed, on north middle lot No. 36, Alma township. It was 1300 feet deep and the oil-sand, 59 feet thick, was struck at a depth of 1212 feet. This well was dry. The next, located on the Crandell farm in lot No. 4, Alma township, and known as the Triangle No. 1, was completed July 4th, 1880. The elevation of the top of this well is 1825 feet; the oil-sand struck at 1109 feet was of a superior quality to that struck in the other wells, and after being torpedoed the well filled up within an hour with 700 feet of oil. A careful record of this well was kept, as follows:

Well-mouth above ocean in feet,			1825
1. Clay, sand and gravel,	100 to	100	= 1725
2. Dark gray shale,	30 to	130	= 1695
3. White sandstone and shale,	40 to	170	= 1655
4. Red shale and sandstone,	15 to	185	= 1640
5. Chocolate shale,	5 to	190	= 1635
6. Red sandstone and shale,	16 to	206	= 1619
7. Chocolate shale and sandstone,	4 to	210	= 1615
8. Gray sandstone containing water,	8 to	218	= 1607

9. Gray sandstone,	12 to	230 =	1595
10. Red sandstone,	6 to	236 =	1589
11. Gray slate,	30 to	266 =	1559
12. Gray shale,	14 to	280 =	1545
13. White shale and sandstone,	3 to	283 =	1542
14. Gray shale,	4 to	287 =	1538
15. Gray sandstone,	4 to	291 =	1534
16. Dark gray sandstone,	7 to	298 =	1527
17. Gray slate,	30 to	328 =	1497
18. Light gray shale,	20 to	348 =	1477
19. Gray slate containing sand shales,	21 to	369 =	1456
20. Light gray slate,	79 to	448 =	1377
21. Gray shale, containing fragments of fossils,	4 to	452 =	1373
22. Soft gray slate,	31 to	483 =	1342
23. Argillaceous sandstone,	22 to	505 =	1320
24 Gray shale,	30 to	535 =	1290
25. Gray shale containing fragments of fossils,	4 to	539 =	1286
26. Red shale,	1 to	540 =	1285
27. Gray slate,	52 to	592 =	1233
28. Gray shale containing fossil remains,	4 to	596 =	1229
29. Gray slate,	21 to	617 =	1208
30. Gray shale, containing fossil remains,	1 to	618 =	1207
31. Soft gray shale,	47 to	665 =	1160
32. Gray sandstone,	40 to	705 =	1120
33. Dark gray shale and slate,	80 to	785 =	1040
34. Gray slate, containing fragments of fossils,	61 to	846 =	979
35. Gray sandy shale, containing fragments of fossils,	9 to	855 =	970
36. Gray shale,	120 to	975 =	850
37. Gray sandstone containing oil and salt water,	20 to	995 =	830
38. Gray shale,	114 to	1109 =	716
39. Soft gray sandstone, top of oil sand,	17 to	1126 =	699
40. Harder gray sandstone,	17 to	1143 =	682
41. Soft gray sandstone, bottom of oil-sand,	10 to	1153 =	672
42. Gray shale and slate,	24 to	1177 =	648
Total depth of well,			1177 feet.

The top of this well is 625 feet below the bottom of the Olean conglomerate, making the distance between the top of the Allegany oil-sand in this well and the Olean conglomerate 1734 feet. The lower 525 feet of this interval of 625 feet is occupied by gray shale and slate and sandstone; above this occurs the sub-Olean conglomerate, which is the middle member of the Pocono sandstone, No. X., ranges from 30 to 40 feet thick, and occurs immediately below the gray shale representing the upper part of the Pocono sandstone, and the red shale representing the Mauch Chunk red shale, No. XI. This section, together with that of the record of the well, can be taken as a representative section of the rocks in the Allegany oil- and

Name of Well.	Location of Well.	Elevation of Well above Tide.	Depth to Top of Oil Sand.	Thickness of Oil Sand.	Elevation of Top of Oil Sand above Tide.
	Scio Township.				
Rilcy Allen, No. 1	Lot No. 2 in Allentown	1805	980	50	825
Allen & Noble	Lot No. 2, Ketchum farm	1990	1188	47	802
Neff	N. W. corner, lot No. 1	1910	1117	25	673
	Alma Township.				
Homestead, No. 1	Lot No. 1 near Allent'wn R.R. sta.	1850	1044	48	806
Triangle, No. 1	Crandall farm lot No. 4	1825	1109	...	718
Royal Oil Co.'s, No. 2	Whitter " " "	1860	1187	...	673
" " " " 1	" " " "	1885	.....	...	.....
Triangle, No. 3		1970	1204	36	766
Wycoff	North middle lot, No. 26	1980	1212	59	768
Central	" " " 6	1950	1218	60	732
Pikeville, No. 1		1775	1028	18 sand 7 slate 18 sand	747
" " 2		1875	1118	30	757*
Duke & Norton, No 1	Lot No. 23	2160	1404	19	756
" " 3	N. W. corner, lot No. 39	2170	1433	37	737
" " 7	Russell farm, lot No. 22	2060	1308	19	752
" " 9	South side " 40	2285	1649	24	636
McCalmont Oil Co., No. 1	Johnson farm, lot No. 3	.....	1387	44	.....
" " " 2	" " "	.....	1333	49	.....
" " " 4	" " "	.....	1285	54	.....
	Wirt Township.				
Taylor & Humphrey, No. 1	Phillips farm, lot No. 17	.....	1490	20	.....
" " " 2	East of lot No 1	.....	1458	18	.....
" " " 3	North of Nos. 1 and 2	.....	1471	21	.....
Flanigan & Cheeseman " 1	Griffen farm, lot No. 41	1650	855	20	795
" " " 2	" " 41	1655	851	4 10 12	804
" " " 3	" " 41	1635	834	18 4 10	801
" " " 4	" " 41	1630	827	32	798
Flanigan & Sanders, No. 2	Sanders farm, lot No. 41	1650	852	38	798
" " " 3	" " 41	1652	839	11	813
	Bolivar Township.				
McCalmont Oil Co., No. 7	Reed farm, lot No. 56	.....	819	29	.....
" " " 8	" " 56	.....	820	32	.....
" " " 9	" " 56	.....	840	44	.....
" " " 10	" " 56	.....	1120	27	.....
" " " 11	" " 56	.....	809	30	.....
D. P. Taylor	William farm, lot No. 37	1920	1208	40	712
Campbell	Southport farm, lot No. 16	1980(?)	1196	35	784
Fisher, No. 1	Miller " " 31	1790	965	30	825
" " 2	Caudell " " 31	1795	1362(?)	18	813 (?)
Klinger, Plumber & Moran	Morse " " 37	1985	1229	8	756
Mutual Oil Co., No. 6	Richardson " " 37	1985	1224	14	761
" " " 7	" " " 37	2000	1240	13	760
" " " 1	" " " 37	1940	1167	22	773
	Wirt Township.				
Richburgh, No. 1		2000	1208	20	792
Morse and Williams	Smith farm lot No. 20	1720	1140	...	580
	Bolivar Township.				
Pliny Parker	Stillman farm, lot No. 25	1795	1300†	...	495
Willett	Mills farm, lot No. 33	1790	1302†	...	488
Waugh & Porter, No. 1	" " 34	1830	1330†	...	500
" " " 2	" " 34	2000	1315†	...	585
Bradley & Co. Gas	" " 28	1785	1062	...	723
Charring Oil Co., No. 8	Richardson farm, lot No. 37	1765	996	...	769
Northrup & Co., No. 1	Lot No. 63	.....	1445	23' 6"	.....
" " 2		.....	1455' 6"	"	.....
" " 4		.....	1299' 6"	"	.....
" " 6		.....	1290	"	.....
	Genesee Township.				
Cranston & Co., No. 1	Hatch farm, lot No. 29	2225	1632	...	593
" " 2	" " 29	2235	1655	...	580

* Elevation of lower Waugh & Porter sand, 425.

† Upper Waugh & Porter sand.

Name of Well.	Location of Well.	Elevation of Well above Tide.	Depth to Top of Oil Sand.	Thickness of Oil Sand.	Elevation of Top of Oil Sand above Tide.
	Genesee Township.				
Willetts, No. 4	N. E. corner, lot No. 3	2035	1308	28	727
" " 19		2125	1402	20	723
" " 25		1980	1259	25	721
Willett	Lot No. 22	.....	1122	...	.....
J. W. Davis, No. 1	S. E. corner, lot No. 31	2035	1410	30	625
" " 2	450′ north of No. 1	1975	1328	34	647
" " 3	" " 2	1920	1256	39	664
" " 4	" " 3	1925	1251	34	674
" " 5	" " 4	1880	1197	30	683
" " 6	" " 5	1810	1108	40	702
" " 7	" " 6	1760	1053	42	707
" " 8	400′ west of No. 7	1768	1058	27	710
Davis & Haldeman, No. 2	Lot No. 24	1675	914	22	761
" " " 3	"	1755	995	20	760
" " " 4	"	1820	1045	28	775
" " " 5	"	1860	1108	14	752
" " " 6	"	1845	1096	15	749
" " " 7	"	1790	1040	35	750
Armour & White, No. 2	Hill farm	1840	1093	35	747
" " 4		1735	959	25	776
" " 5		1785	1017	14	768
" " 6		1765	995	12	770
" " 7		1735	963	27	772
" " 8		1715	955	19	760
	Clarksville Township.				
Davis & Haldeman, No. 8	Lot No. 17	1785	1064	15	721
" " " 9	"	1835	1100	(15 sand) 5 slate (15 sand)	735
" " " 10	"	1770	1058	10	712
" " " 11	"	1850	1103	(15 sand) 29 slate (10 sand)	747
" " " 12	"	1915	1182	10	733

gas-district. An outcrop of the sub-Olean conglomerate may be seen facing the Genesee river a mile and a half north of Wellsville; the elevation of the rock at this point is 2160 feet. Another outcrop, the elevation of which is about 2000 feet, may be seen facing the Genesee river 6 miles south of Wellsville.

During 1880 there were 50 wells drilled in the Allegany oil-field, 42 of which contained either gas or an unprofitable amount of oil; 8 wells produced oil at an average of 9½ barrels per well. It was not until 1881 that the oil-trade attached any importance to the oil-developments in Allegany County. To Mr. O. P. Taylor more than to any one else is due the credit of advancing the oil- and gas-interests of the Allegany district.

The general geological structure of the Allegany oil- and gas-district is clearly defined by the selected well-records on pp. 27 and 28, the geographical position of which can be ascertained by referring to the corresponding township and lot number on the map.

These records show that the top of the Allegany oil- and gas-sand

Name of Well.	Location of Well.	Length of Casing.	Depth to Top of Oil Sand.	Depth to Bottom of Oil Sand.	Total Depth of Well.	Remarks.
Gilchrist, No. 1	Merritt farm		1180	1200	1219	
Green, " 1	Green "	387	1441	1455	1471	
" " 2	" "	290	1307	1315	1358	Casing pulled out and plugged.
" " 3	" "	405	1492	1514	1534	
" " 4			1417	1456	1471	Casing pulled out and plugged.
Stillman " 1	Stillman farm	497	1030	1047	1068	
" " 2	" "	405	1132	1146	1163	Casing pulled out.
" " 3	" "	447	1005	1023½	1042	"
" " 4	" "	403	1119	1135	1152½	
Young " 2	Young "	400	1500	1515	1530	
Hardison " 5	Merritt "		1216	1259	1275	Gas struck at 1200'.
" " 6	" "	283	1284	1301	1340	" " 1238'.
Fisher " 1	Fisher "		1196			
" " 2	" "		1268			
" " 3	" "		1452			
" " 4	" "		1437			
" " 5	" "	342	1073	1098	1118½	Gas struck at 1055'. [and 1161'.
" " 6	" "		1134	1167	1179	" " 1112', slate bet. 1146'
" " 7	" "		1304	1324½	1335	" " 1269'.
Anderson " 1	Woodward "		1019	1046	1065	
" " 2	" "		1017	1027	1067	Gas struck at 953'.
" " 3	" "	490	1224	1238	1256½	" " 1162' through 1216'.
Labar " 1	Labar "		1255	1316	1365	
		360c'g				
Adams, " 1	Adams "	57 dr. pipe	1117	1138	1158	
Wiser & Kinkaid, No. 2	Ford "		1340	1392	1415	Gas struck at 1260' to 1280'.
Chase & Mallory, " 1	" "			1280	1281	
" " 2	" "			1321	1356	
Jordon, No. 1	Jordan h'rs "		920	940	973	
Wells, " 1	Wells "	492	1665	1688	1714	
Stives, " 1	Stives "	340	1545		1605	Gas struck at 1500'.
			1st 1094	1110		
Smith, " 1	Springer "	300	2d 1129	1150	1165	
			1121	1137		
" " 2	" "	310	1146	1173	1192	
			1160	1172		
" " 3	" "	315	1179	1210	1234	
" " 4	" "	300	1170	1201	1241	
			1196	1216		
" " 5	" "	290	1229	1237	1259	
			1st 1064			
			2d	1090		
" " 6	" "	405	1119	1126	1175	
			3d 1148	1157		
Fitz, " 1	Fitz "		1272		1324	Gas struck in sand at 1238.
Wells, " 2	Wells "		1640	1662	1685	36 qt. torpedo exploded in sand.
" " 2	" w'ter well					478 ft. deep.
Howe, " 3	Howe farm		1338	1366	1400	Slate, 1327 to 1332, 40 qt. torpedo exploded sand.
Lesker, Jordan & Co. No. 1			1271	1289	1319	Gas at 1187, slate at 1206, gas from 1232 to 1247, shot with 40 qt. torpedo.
Campbell Oil Co. Sawyer No. 3, or Campbell No. 8.	Ira Sawyer farm		1272	1295	1326	Gas at 1200.
Chase & Mallory, No. 1		236	1230	1248	1286	
" " 1		250	3d 1280	1320	1356	
			gas	to		
R. Allen. " 2		338	sand 1222	1246	1350	
Jordan Heus, " 2		304				
Hogan, Murphy & Basele, No. 1		400			1018	Struck gas at 963, oil at 981—18 ft. gas sand, 18 ft. oil sand.
Hogan, Murphy & Basele, No. 2		370			1012	Struck gas at 947, oil at 970—23 ft. gas sand, 14 ft. oil sand.
Hogan, Murphy & Basele, No. 3		378			1006	Struck gas at 946, oil at 966—20 ft. gas sand, 18 ft. oil sand.
Hogan, Murphy & Basele, No. 4		410			1054	Struck gas at 988 oil at 1020—22 ft. gas sand, 12 feet oil sand.

is extremely undulating, and in many localities has excessive dips. For instance, the dip of the sand between the Davis and Haldeman's wells and the Davis well No. 1 is at the rate of 160 feet to the mile. The greatest dip which I have ever observed in the Bradford sand within the main Bradford district is between Tarport and State Line, 18 feet to the mile. This comparatively heavy and variable dip in the Allegany district, I think has been the cause of confusing the geology of the district, as compared with that of Bradford, in the minds of both geologists and operators.

The topography of the top of the Allegany oil- and gas-sand may be more fully appreciated by designating on the map (Plate III) the elevation above tide of the sand at each well included in the above list. In addition to this list of wells, the locations of which are all directly referable to the map, I have compiled a list of a few of the other well-records in my possession in order to show especially (1) the depths at which all surface fresh water is cased off; (2) the thicknesses in different localities of the oil and gas-sand; and (3) the depth to which the wells have generally been drilled below the producing sand. These records are noted in the preceding table (p. 29).

Most of the gas-wells in the Allegany district are at present controlled and operated by the Empire Gas and Fuel Company, Limited, of Wellsville. In the spring of 1887, this company had about 2000 individual consumers along its various pipe-lines, which measured in the aggregate about 125 miles, the pipes ranging from 8 inches to 2 inches in diameter. At the same time the company owned 102 wells, 73 of which produced oil, 4 oil and gas combined, and 25 gas alone. These wells are enumerated in the following list. No measurement has ever been made of the actual production in cubic feet of any of the gas-wells in the district, but the relative productive capacity of the gas-sand in different parts of the field is shown by the maximum pressure of the gas which will accumulate in the wells noted in the table.

No.	Lot.	Township.	Farm.	Character of Well.	Highest Confined Pressures at gas-wells. Pounds.	In Minutes.
1	11	Genesee,	Dancy,	Gas,	50	—
2	21	"	Bullock,	Oil,	—	—
3	21	"	"	"	—	—
4	21	"	"	"	—	—
5	14	"	Young,	"	—	—
6	14	"	Green,	"	—	—
7	14	"	"	"	—	—
8	7	"	Stillman,	"	—	—

No.	Lot.	Township.	Farm.	Character of Well.	Highest Confined Pressures at gas wells. Pounds.	In Minutes.
9	7	Genesee,	Stillman,	Oil,	—	—
10	7	"	School House,	"	—	—
11	16	"	Merritt,	"	—	—
12	16	"	"	"	—	—
13	16	"	"	"	—	—
14	16	"	"	"	—	—
15	16	"	"	"	—	—
16	9	Clarksville,	"	"	—	—
17	9	"	"	"	—	—
18	9	"	"	"	—	—
19	17	"	Springer,	"	—	—
20	17	"	"	"	—	—
21	17	"	"	"	—	—
22	17	"	"	"	—	—
23	17	"	"	"	—	—
24	17	"	"	"	—	—
25	3	"	Adams,	Gas,	90.7	—
26	3	"	McJordan,	"	90.7	—
27	2	"	Painter,	"	90.7	—
28	2	"	Lovell and Willett,	"	90.7	—
29	59	Wirt,	Lebar,	"	100	21
30	60	"	Isaiah Jordan,	"	100	16
31	61	"	Deyoe,	"	130	—
32	51	"	W. Jordan,	"	95	25
33	51	"	"	"	125	20
34	58	"	Ballard,	"	85	17
35	50	"	Evans,	"	70	10
36	49	"	Barton,	"	70	—
37	51	"	Jordan heirs,	"	110	7
38	51	"	"	"	117	Shut in.
39	43	"	Knox,	Oil and gas,	—	—
40	43	"	"	"	100	3
41	43	"	"	"	100	3
42	34	"	Richardson,	Gas,	140	15
43	34	"	"	"	140	—
44	34	"	Lawrence,	"	150	17
45	26	"	Brown,	"	Drowned out by oil.	
46	26	"	Patterson,	"	100–100	—
47	30	Bolivar,	J. Goodrich,	Oil,	—	—
48	30	"	"	"	—	—
49	30	"	"	"	—	—
50	30	"	"	"	—	—
51	30	"	George Beers,	Gas,	Drowned out by oil.	
52	22	"	Wakeman,	"	125	—
53	30	"	Goodrich,	Oil,	—	—
54	14	"	Fitzgerald,	"	—	—
55	14	"	Sawyer,	"	—	—
56	15	"	Anderson,	"	—	—
57	15	"	"	"	—	—

No.	Lot.	Township.	Farm.	Character of Well.	Highest Confined Pressures at gas wells. Pounds.	In Minutes.
58	15	Boliver,	Anderson,	Oil,	—	—
59	15	"	Sawyer,	"	—	—
60	15	"	"	"	—	—
61	15	"	"	"	—	—
62	15	"	"	"	—	—
63	8	"	Ford,	"	—	—
64	8	"	Dunham,	"	—	—
65	8	"	"	"	—	—
66	8	"	"	"	—	—
67	16	"	Wetherby,	"	—	—
68	16	"	"	"	—	—
69	16	"	"	"	—	—
70	16	"	"	"	—	—
71	16	"	"	"	—	—
72	16	"	"	"	—	—
73	16	"	"	"	—	—
74	16	"	Howe,	"	—	—
75	16	"	"	"	—	—
76	16	"	"	"	—	—
77	8	"	Wiser and Kincaid,	"	—	—
78	8	"	"	"	—	—
79	8	"	Dunham,	"	—	—
80	8	"	"	"	—	—
81	8	"	Ford,	"	—	—
82	8	"	"	"	—	—
83	8	"	S. Wetherby,	"	—	—
84	8	"	"	"	—	—
85	8	"	"	"	—	—
86	8	"	Glycerine Lot,	"	—	—
87	1	Alma,	Noff,	Oil and gas,	—	—
88	1	Wert,	Drumb,	Oil,	—	—
89	1	"	Riley Allen,	Gas,	—	—
90	1	"	"	"	110	—
91	9	"	Wright,	Oil,	100	—
92	24	Bolivar,	Phillips,	"	—	—
93	24	"	"	"	—	—
94	24	"	Wright,	"	—	—
95	24	"	"	"	—	—
96	24	"	"	"	—	—
97	24	"	Crandall,	"	—	—
98	24	"	"	"	—	—
99	24	"	"	"	—	—
100	24	"	"	"	—	—
101	3	Alma,	Pike,	"	—	—
102	3	"	"	"	—	—

The peculiar character of the gas-sand in the Allegany district is such that I believe we can safely anticipate that no sudden termi-

nation will come to the production of gas, but that the decline will be more gradual than the decline of other gas-districts which draw their supplies from coarser and more open gas-rocks.

The prices charged the consumers by the Empire Gas and Fuel Company, Limited, are as follows:

Cook stoves,	$3.50 per month.
Heating stoves, according to the size of the room, ranging from	$3 to $6 per month.
Lights in dwellings,	$0.25 per month.
Lights in stores,	$0.30 per month.
Boilers, from	$1.25 to $1.50 per day.
Furnaces, from	$6 to $9 per month.

Although the Allegany gas-wells differ in many respects from those of Northern Pennsylvania, yet in the main the history of these wells will no doubt be found to be much the same as the history of the gas-wells in Northern Pennsylvania, particularly those in northern McKean County.

Oil- and Gas-Sands of Pennsylvania.

An interesting practical question relating to the geology of the Allegany oil- and gas-district is the relationship of the Allegany sand to the oil- and gas-sands in other regions, particularly those in Pennsylvania, southwest as far as Pittsburgh. The strata so far found to contain natural gas in commercial quantities between Allegany County, New York, and Washington County, Pennsylvania, occur within a vertical range of about 3000 feet, are all of the Carboniferous and Devonian group of rocks, and extend from the Mahoning sandstone, at the base of the Lower Barren Coal Measures, and, on an average, about 500 feet below the great Pittsburgh coal-bed, down to the Roy and Archer oil- and gas-sand in Elk County. A small show of gas is found in Greene County, Pennsylvania, in two sandstones, one 165 feet and the other 425 feet respectively below the Pittsburgh coal-bed. These sandstones are above the Mahoning sandstone referred to; but since they do not produce gas in commercial quantities they are not considered here. Next below the Mahoning sandstone, gas has been found in Washington County, in what is known as the Homewood sandstone, a member of the Pottsville Conglomerate No. XII., which lies at the base of the Lower Productive Coal Measures. The next rock below the Homewood which has produced gas in commercial quantities is the Pit

Hole Grit, a representative of the Berea Grit of the Ohio Survey. This sandstone is about 1725 feet below the Pittsburgh coal-bed, and between 800 and 900 feet below the Homewood sandstone.

Next below the Berea Grit, and immediately below the Pit Hole Grit (which rocks are probably the same), occur the sands of the Venango-Butler oil- and gas-sand group, which are representatives of the Catskill Old Red sandstone strata. In the upper part of this group is located the great Murrysville gas-sand, from which almost the entire gas-supply of Pittsburgh is derived. This group varies from 300 to 600 feet thick, being thinner in the northern part of Pennsylvania, and thicker in the southwestern corner of the State; next below this group occur from 300 to 350 feet of shales of the Chemung, which produce no gas. Below this barren interval are the Cherry Grove oil-sand and the Sheffield gas-sand of southern Warren County, which occur about 200 feet below the base of the Warren group; from 300 to 400 feet below the Warren group lies the Bradford or Alleghany sand. The only sands which have so far been found to produce gas below the Bradford or Alleghany gas-sand are the Cooper sand in Warren County, which, however, is probably one of the members of the Bradford sand, or the upper oil-sand of the Waugh and Porter well in Allegany County, N. Y., and the Roy and Archer well sand in northern Elk County. This latter sand occurs about 500 feet below the Bradford sand and about 1800 feet below the geological horizon of the Murrysville sand. All the gas-sands above referred to are in the Portage and Chemung formations. No clear division-line between these two formations has ever been established.

The geographical relationship of the Allegany district to the oil and gas-districts of Western Pennsylvania and the geological relationship of the oil- and gas-sands from Allegany County southwest to Washington County, Pennsylvania, are shown by the map and columnar sections on the accompanying chart (Plate II.).

Largest Producing Gas-Well in New York.

The greatest amount of gas which was ever discharged per diem from any well in New York State was from the McMullen & Hallock gas-well, commonly known as the "Mullen snorter." This well is located on the Loup farm, section 1, in the extreme southwest corner of Olean township, Cattaraugus County, and in an air-line $5\frac{1}{2}$ miles south-southwest of the village of Olean. Gas was struck in this well on the 30th of May, 1877. The elevation of the

top of the well above tide is 1785 feet. Solid rock was struck at a depth of 16 feet, and at a depth of 196 feet all the surface-water was cased off. The strata above the depth of 625 feet were composed of gray shales and slate, with occasional thin seams of sandstone. From 625 to 675 feet a fine-grained "shelly" sandstone 50 feet thick was pierced. Below this sandstone, and to a depth of 870 feet, strata were passed through similar in character to those in the other part of the well. From 890 to 960 feet a fine-grained sandstone, alternating with shale, was drilled through. Gas was first encountered in the well at a depth of 1180 feet in a sand-bed which was 25 feet thick. The Bradford oil- and gas-sand proper was struck at a depth of 1230 feet. I visited this well June 1st, 1877, and from careful measurements estimated the discharge of gas to be at the rate of 17,000 cubic feet per minute, or 24,480,000 cubic feet per twenty-four hours. There was discharged in conjunction with the gas about a barrel of oil per day. The top of the oil-sand in this well is 1785 feet below the bottom of the Olean Conglomerate, which outcrops at the famous Olean Rock City. The gas-sand in the vicinity of this well is nearly horizontal, having only a dip of about 11 feet per mile in a direction south 15° west. The discharge of gas continuously decreased until 1882. Since that date the well has produced from two to three barrels of oil per day, with a comparatively small amount of gas. This well is interesting for several reasons: First, it is the largest gas-well ever found in the State of New York, and one of the largest in the Bradford oil-pool; second, the well, although a large gas-producer, is not located on an anticlinal, but in a synclinal; third, on account of the intimate association of oil and gas in the well, and the short life of the gas-flow; fourth, this well produced more gas per day than any well whose discharge had ever been measured up to June, 1877. There is no doubt that larger gas-wells had previously been obtained in Pennsylvania, but the discharge of none of the larger Pennsylvania wells had ever been actually measured.

Explorations for Gas in Central New York.*

Professor Charles S. Prosser, Assistant in the Geological Laboratory at Cornell University, has for some time been engaged in obtaining as far as possible a record of the test-wells drilled in New

* These notes and also those relating to natural gas in Ontario County have been kindly furnished by Professor Prosser for original publication in this place.

York outside of the Allegany oil- and gas-field, with the view not only of ascertaining the facts connected with the discovery of natural gas, but also of determining the thickness of the different geological formations. These facts Professor Prosser is tabulating with the expectation of using them as a basis for a paper on the stratigraphical geology of New York State. They have been gathered principally in the central part of western New York. He has furnished them to me with such brief references as may make them intelligible for publication in this connection.

Record of Well Drilled at Ithaca, Tompkins County. Location, in the Valley, One-Quarter Mile South of Ithaca.

	Well-mouth above ocean in feet,		. 396
	1. Lower Portage shales,	340 to 340 = +	56
	2. Genesee shale,	100 to 440 = —	44
	3. Tully limestone,	30 to 470 = —	74
	4. Hamilton group; composed of argillaceous and arenaceous shales, thin sandstones with calcareous shales and sandstones,	1142 to 1612 = —	1216
	5. Marcellus shale,	82 to 1694 = —	1298
	6. Corniferous limestone,	78 to 1772 = —	1376
	7. Oriskany sandstone,	13 to 1785 = —	1389
	8. Lower Helderberg limestones,	115 to 1900 = —	1504
Salina or Onondaga Salt Group.	9. Shale,	344 to 2244 = —	1848
	10. Rock salt,	24 to 2268 = —	1872
	11. Shale,	6 to 2274 = —	1878
	12. Rock salt,	54 to 2328 = —	1932
	13. Shale,	12 to 2340 = —	1944
	14. Rock salt,	17 to 2357 = —	1961
	15. Shale,	31 to 2388 = —	1992
	16. Rock salt,	21 to 2409 = —	2013
	17. Shale,	67 to 2476 = —	2080
	18. Rock salt,	42 to 2518 = —	2122
	19. Shale,	24 to 2542 = —	2146
	20. Rock salt,	48 to 2590 = —	2194
	21. Shale,	82 to 2672 = —	2276
	22. Rock salt,	42 to 2714 = —	2318
	23. Green shale,	308 to 3022 = —	2626
	24. Mottled red and green shale,	6 to 3028 = —	2632
	25. Green shale,	102 to 3130 = —	2734
	Depth of well (December 15th, 1887, in Salina shale),		3130 feet

The total depth of the well, as given by Mr. Rust, the contractor, is 3185 feet. The record stops at 3130 feet.

The largest amount of gas was obtained from the last 30 feet of

the Genesee shale and the first 50 feet of the Hamilton shales, below the solid 30 feet of Tully limestone. When the gas was lighted, the flame reached from 4 to 8 feet in height. There was no particular increase in the amount of gas when the Marcellus shales were reached. A small amount of gas with a very disagreeable odor was obtained in the Lower Helderberg limestoues.

Record of Well Drilled at Clyde, Wayne County. Location, in Clyde Village. Altitude, approx., 389′ *A. T.*

Salina Group.	1. Gray, green and blue marls with gypsum,	152 to	152 = +	246
	2. Red marls,	156 to	308 = +	90
	3. Blue and green marls,	32 to	340 — +	58
	4. Dark blue limestone, upper division of Niagara group,	110 to	450 = —	52
	5. Shaly limestone, lower division of Niagara,	225 to	675 = —	277
	6. Clinton group: oölitic iron ore in sample from 675′–690′,	83 to	758 = —	360
	7. Red shale of Medina,	24 to	782 = —	584
	8. Greenish-gray sandstone,	3 to	785 = —	587
	9. Red shales alternating with red sandstone and forming the Red Medina,	915 to	1700 = —	1502
	10. Gray Medina or gray sandstone of Oswego (Vanuxem),	92 to	1792 = —	1594
	11. Depth of well (in Gray Medina),			1792 feet

At 380′, in the blue Niagara limestone, some gas was obtained, and so on to about 500′. The flow of gas has continued the same during the two months that have passed since it was found. At 685′ a "pocket" of gas was developed in the Clinton which was soon exhausted. The gas, when lighted, supports a flame 3 or 4 feet high.*

* Mr. George O. Baker, Secretary of the Clyde Mining Company, under date of February 21, 1888, furnishes the following facts relating to the Clyde exploration well. Mr. Baker has grouped the strata passed through from observations made by Professor Prosser.

"A few facts regarding the well may not be uninteresting. A corporation was organized in May, 1887, with a capital of $3000. In the summer a contract was made, and drilling commenced on the vacant lot near the glass works, September 13th. Plaster rock was reached at 20 feet; this, with gray, green and blue marls, continued until at 152 feet red shales were struck, and these continued until 108 feet from the surface had been reached, then 32 feet of light blue and greenish marl. These formations are understood to be the lower part of the Salina or Onondaga salt group. At 340 feet the Niagara limestone was reached and continued to 675 feet; the upper 110 feet being dark blue limestone of the upper division of the Niagara,

Record of Well Drilled at Wolcott, Wayne County. Location in the Ravine at Wolcott Village. Altitude, approx., 317′ A T.

1. Shaly layers of Niagara limestone above and Clinton below, thickness of shales below top of latter not determined,	214 to	214	= + 103
2. Oölitic iron ore and shales of Clinton, group,	16 to	230	= + 87
3. Red shale alternating with red, siliceous sandstone, forming the Red Medina,	690 to	920	= — 603
4. Gray Medina or Oswego sandstone of Vanuxem,	210 to	1130	= — 813
5. Some blue shale alternating with gray siliceous sandstone, similar to the Oswego sandstone,	170 to	1300	= — 983
6. Undoubted Hudson River blue shale,	55 to	1355	= — 1038
7. Gray sandstone containing gas, followed by dark blue shale,	5 to	1360	= — 1043
8. Lower part of Utica shale,	590 to	1950	= — 1633
9. Compact blue limestone alternating with shaly layers forming top of Trenton,	750 to	2700	= — 2383

Gas was found at 2092 and at 2330, the larger amount being found at the latter depth.

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and the lower 225 feet the shaly limestone of the same Niagara group. At 675 feet, the Clinton group was reached, and continued to 758 feet, the upper 15 feet being a greenish shale with traces of iron, and the balance a dark gray limestone. At 758 feet the 'Red Medina' was reached, and this, with varying color, continued to 1700 feet. At this depth the Gray Medina or Oswego sandstone was reached, and the drilling was continued in this to the depth of 1792 feet, when operations were suspended, November 23d, 1887.

"Complete samples of the drillings have been furnished to Prof. Charles S. Prosser, of Cornell University, and much valuable information has been received from him. The specimens are in the Geological Laboratory of the University, and a complete set of samples will be furnished for the laboratory of the Clyde High School as soon as the same can be properly arranged.

"At 360 feet gas was indicated, and at 380 feet quite a flow was obtained. At 685 feet a 'pocket' of gas was struck, which, for a short time, increased the flow perceptibly. Not much change has occurred in the flow since drilling has ceased; at least, there has been no decrease.

"At 110 to 120 feet the same mineral water was found, which is somewhat common here, apparently the same as at the old spring by the river, at Streeter's malt house and at the glass factory.

"At 175 feet a very strong salt water was found, also in a crevice at the depth of 340 feet (top of Niagara), salt water was found.

"The well is thoroughly cased to the depth of 352 feet, 11 inches with extra heavy casing, completely shutting off the water, and from thence to the bottom is what may be called a 'dry hole.' It is to be hoped that enough interest may be taken to furnish the needed money to reach a depth of 3000 feet, which will sufficiently penetrate the Trenton, the famous gas-bearing rock, to demonstrate whether gas in paying quantity can be found in Clyde."

The upper portion of the Trenton limestone in the Wolcott well, and probably for a considerable distance both east and west of this village, is a very compact rock. Deeper the limestone becomes more shaly and in this part of the formation the gas was obtained. The great difference in the structure of the western and eastern Upper Trenton limestone is readily seen when samples of the drillings from Ohio or Indiana wells are compared with those from this well. The porosity of the western Trenton seems to be almost entirely wanting in this part of New York.

Mr. H. W. Hatch, of Richburgh, who drilled the Wolcott well, states that when the well was finished in the latter part of October, 1887, the well produced, by meter measurement, 5000 cubic feet of gas per day; on December 1st, the production remained the same.

Some gas was obtained from 1100 feet on; the largest amount came from the sandstone at 1355 feet in the Hudson River group. Gas was got in the Trenton limestone first at 2092 feet, and the largest quantity at 2330 feet. Pieces of the limestone were thrown out of the well from the 2330 feet "pocket" and it is claimed that the flame of the gas when lighted, was from 15 to 20 feet high.

From a partial record of a well drilled in Ontario, Wayne County, New York, I am inclined to think that the bottom of the Wolcott well is within about 100 feet of the bottom of the Trenton series, below which is 100 feet of Calciferous limestone before the Archæan can be reached.

Record of State Well at Syracuse, from the Report of the Superintendent of the Onondaga Salt Springs, N. Y. Assembly Doc., No. 32, for 1885, *page* 15.

Salina.	1. Drift, 2. Red marls,	555 to	555 = —	155
	3. Variegated marls and limestones,	23 to	578 = —	178
	4. Niagara limestone,	342 to	920 = —	520
	5. Clinton shales and iron-ore,	105 to	1025 = —	625
	6. Transition shales,	50 to	1075 = —	675
	7. Red brown sandstone of the Medina,	100 to	1175 = —	775
	8. Red sandstone alternating with gray and brown sandstones,	640 to	1815 = —	1415
	9. Gray Medina or sandstone of Oswego,	154 to	1969 = —	1569
	10. Bottom of well in Gray Medina,			1969

An examination of the records of the Wolcott, Clyde and State wells shows a considerable variation in the thickness of the Red Medina. It is 690 feet thick in the Wolcott well, 942 feet in the Clyde and from 740 feet to possibly 810 feet in the State well at

Syracuse. A difference of 252 feet in the thickness of the Red Medina in the Wolcott and Clyde wells, which are on nearly a north and south line, shows a considerable thickening of this formation to the southward. The diminished thickness of the Red Medina in the State well, thirty miles east of Clyde, agrees with the known thinning of the Medina to the eastward.

Southward from Ithaca to Pennsylvania, the thickness of the formations can only be estimated. This portion of the geological series includes the three following formations in ascending order from the Genesee Shale and Lower Portage of H. S. Williams: The Ithaca group of Vanuxem, Upper Portage of H. S. Williams and the Chemung. Prof. Hall estimated the thickness of what he calls Chemung (which includes Williams' Upper Portage and Vanuxem's Ithaca group) to be 1500 feet for this section of New York (see Geol. Rept., 4th dist., p. 260); while Prof. H. S. Williams has given the thickness of the same series as about 1950 feet. (See Bulletin No. 3, U. S. G. S.)

Section from the Top of the Genesee Shale on Cayuga Lake, New York, to Ulster, Bradford County, Pennsylvania, and thence to the Barclay Coal Field. Compiled from Surveys of Prof. H. S. Williams. (Bul. No. 3, U. S. Geol. Survey.)

		Feet.
	Barclay lower coal-bed,	——
XII. XI. X. IX.	Pottsville Conglomerate, Mauch Chunk Red Shale, Pocono Gray Sandstone, Catskill Red Sandstone,	1000
	Upper Chemung fauna in Penna. (Top at Ulster),	300
	Typical Chemung fauna (Outcropping in vicinity of State Line, bottom of Chemung Narrows, New York),	300
	Lower Chemung fauna. (Bottom outcrops at Caroline, Danby and Newfield),	600
VIII.	Upper Portage Sandstones and Shales of H. S. Williams,	600
	Middle Portage: Upper Ithaca,	200
	Middle Portage: Typical Ithaca,	100
	Middle Portage: Lower Ithaca,	150
	Lower Portage Sandstones and Shales,	250
	Genesee Shales,	——
	Total thickness,	3500

All the facts given in the above section are not clearly expressed in the Bulletin; but Prof. Williams has kindly furnished me with a diagram which has been used somewhat in the preparation of this section. The report on Bradford County (Geol. Survey, Penna., Report G.) has been of assistance in compiling that portion of the section above the Upper Chemung.

From the sections already given there has been constructed a section giving the thickness of the different geological formations, together with the total thickness of the series from the lowest coal-measures down to the Archæan. The section commences with the lower coal of Barclay, Penna., passes through Waverly, Ithaca, Clyde and Wolcott, N. Y., under Lake Ontario and to the Archæan of Ontario. The thickness of the formations from the Barclay coal to the Ithaca shale at the top of the Lower Portage is estimated, while for the remainder of the series it has been obtained from the wells drilled at Ithaca, Clyde, Wolcott and Ontario.

Section from Barclay, Pennsylvania, through Central New York to Ontario, Canada.

		Feet.
	Barclay lower coal-bed,	
XII.	Pottsville Conglomerate,	
XI.	Mauch Chunk Red Shale,	
X.	Pocono Gray Sandstone,	1000
IX.	Catskill Red Sandstone,	
VIII.	Chemung Sandstones and Shales,	1200
	Portage Sandstones and Shales,	1390
	Genesee Shales,	100
	Tully Limestone,	30
	Hamilton Sandstone,	1142
	Marcellus Shales,	82
	Corniferous Limestone,	78
VII.	Oriskany Sandstone,	13
VI.	Lower Helderberg Limestone,	115
	Salina Shales,	1418
	Niagara Limestone and Shales,	335
V.	Clinton Shales and Sandstone,	83
IV.	Medina Red Sandstone,	942
	Medina or Oswego Gray Sandstone,	210
III.	Hudson River and Utica Sandstones, Shales and Slates,	820
II.	Trenton Limestone,	842
	Calciferous Limestone,	
I.	Potsdam Sandstone,	150
	Total thickness,	9950

The geologic horizon of the gray limestone found in the lower part of the Ontario well is in doubt. The base of the Trenton north of Lake Ontario varies from a dark blue, sometimes massive and sometimes shaly limestone, to a "pale drab limestone of fine texture." —(*Geology of Canada*, page 190.)

Below the Black River, at Madoc, Province of Ontario, which is almost directly north of the village of Ontario, New York, and also at Marmora, west of Madoc, occur shales, sandstones, and light gray limestones from 40 to 80 feet in thickness, the geologic horizon of which is uncertain.—(*Ib.*, page 182 and page 177.)

"Below Knowlton Lake (which is nearly north of Kingston) no indications of the Potsdam formation has been observed in Canada, unless 8 feet of red soft calcareous sandstone at Marmora resting on the Gneiss, and succeeded by certain beds of limestone, without observed fossils, for 30 feet upwards have been supposed to represent it."—*Ib.*, page 100 and page 179.)

Following the Potsdam where this is present, and resting on the Laurentian series where it is wanting, there are generally met with 30 or 40 feet of strata almost destitute of organic remains, and about the same amount with a few fossils insufficient to determine the age of the strata with certainty. The first well-characterized beds which succeed these belong to the river formation.—(*Ib.*, page 119.)

Therefore, it is quite possible that part of the light gray limestone found in the Ontario well at a depth of 2810 feet, may belong to the lower part of the Trenton formation, while the lower may or may not represent the Calciferous formation.

Natural Gas in Ontario County.*

The western part of Ontario County is the only portion of central and northwestern New York that, at present, is producing natural gas in economic quantity. The wells commence in the Genesee shale or Hamilton group, and pass through the Marcellus shale to the Corniferous limestone. The gas is obtained in the lower part of the Marcellus shale, and this gas territory is in the vicinity of the now famous West Bloomfield well. This well, I am informed, was drilled in 1863–64,† gas being obtained at about 500 feet, and the Corniferous limestone having been reached at 550 feet *approximately*. In 1870 Professor Henry Wurtz† stated that the gas came from a

* Notes furnished by Professor Charles S. Prosser.

† Prof. Wurtz's article makes the date of drilling about 1866.—Am. Jour. Sci. and Arts (2), vol. xlix., p. 336.

5-inch pipe, and gave, "in a still atmosphere, a flame some 30 feet in height." Professor Wurtz was inclined to think that the report that the well yielded "about 400,000 cubic feet of gas per day," might be true.*

An attempt to conduct the gas to Rochester in wooden pipes was a failure, and the well was filled with stones, old iron, etc. After this, for some years, the flow of gas was very small, but it is increasing again, and is reported by Mr. Peter R. Reed to be sufficient for five or six stoves.

Mr. Charles Ward, Secretary of the Honeoye Gas and Mining Company, Limited, has very kindly given me some facts in reference to the business of that company which are of interest in this connection. This company has one well at the foot of Honeoye Lake, 646 feet deep to the top of the Corniferous limestone, and intends shortly to drill additional wells. Most of the gas in this well is obtained at a depth of 610 feet, and the entire gas-pressure is reported as about 90 pounds. The company has laid 3000 feet of 3-inch pipe, 3000 feet of 2-inch pipe, and about 2000 feet of 1-inch pipe through Honeoye village, and at present is supplying 26 stoves from this well at a cost to the consumers of $3.00 per month for each stove. The plant has cost the company not over $6000.

The Ontario Gas and Improvement Company has drilled several wells about five miles north of the Honeoye Lake well in West Bloomfield township. These wells reach the Corniferous limestone at a depth of about 420 feet, and the average pressure of each well is reported to be about 35 pounds. These two companies are the only ones at present developing this territory in Ontario and Livingston counties.

Mr. Hardy, the Superintendent of the Ontario Gas and Improvement Company, reports that his company has piped the villages of West and North Bloomfield in the northwestern part of Ontario County, and Honeoye Falls in the southeastern part of Monroe County. No measurement has been made of the amount of gas which the wells are producing, but they are supplying constantly 146 stoves

* Am. Jour. Sci. and Arts (2), vol. xlix. pp. 336–7. See the Geologic Dist. of Nat. Gas in the U. S., by C. A. Ashburner, p. 18. Also, in Johnson's (Revised) Univ. Cyclopædia, vol. iii., article, Gas-Lighting, p. 385, by Dr. C. F. Chandler, is the following statement: "A wonderful gas-well occurs at Bloomfield, Ontario County, N. Y. It was bored to a depth of 500 feet for oil, and yields 800,000 cubic feet, daily, of 14½ candle-gas." In answer to a note of inquiry I received the following remarkable answer from Dr. Chandler: "In reply to your favor, I would say that I am not the Prof. Chandler referred to, in connection with the gas-well in Ontario County, nor have I any idea who the professor is."

and furnaces with gas. Twelve wells have been drilled, five of which were dry, producing no gas, and of the remaining seven wells each produces about the same quantity of gas. The Corniferous limestone in these wells is struck at depths ranging from 420 to 500 feet.

Mr. Ward reports some samples of petroleum from this region.

The Genesee shales overlying the Hamilton group are reported as very bituminous in Ontario County along the shores of Canandaigua Lake. Professor J. M. Clarke, describing these shales, says:

"Along the shores of Canandaigua Lake, where the strata have an excellent development, there are at the base of the group about 20 feet of bituminous arenaceous shale, containing rows of concretions of impure calcic-carbonate, this overlaid by 40 feet of densely bituminous rock having a perfect cleavage that gives it a close resemblance to a slate. This bed is so rich in organic matters that the heat from a blow of the hammer evaporates enough of the lighter hydrocarbons to produce a very strong petroleum smell. Over limited areas it loses its schistose character, becomes compact and densely rich in bituminous matter.

Petroleum has been reported from several wells in the Canandaigua Lake region. The largest amount is reported by Professor S. F. Peckham, as obtained from a well drilled on the east shore of Canandaigua Lake in 1865, by Jonathan Watson, of Titusville, Pennsylvania. It is stated that at first this well produced five barrels of oil per day.

In the vicinity of Seneca Falls, about 12 miles southeast of Clyde, a well has been drilled, the top of which is geologically located in the Upper Salina formation. The mouth of the well is less than 75 feet below the base of the light drab limestone which Professor James Hall regarded as belonging to the last division of the Salina. (Geology of New York, Part IV., p. 123.)

The facts in regard to this well are as follows:

		Feet.
Approximate elevation of well-mouth above tide, . .		385
1. Drab ash-colored impure limestones, . . .	200 to 200 =	185
2. Blue marls, with a few streaks of red-green shale, .	100 to 300 =	85
3. Greenish-gray marl, ...	400 to 700 = —	315
4. Red shale, containing a few layers of mottled red and green shale, ...	250 to 950 = —	565
5. Dark-blue limestone, Niagara and Clinton formations, ...	400 to 1350 = —	965
6. Red shale and sandstones of Medina formation, .	150 to 1500 = —	1115
Total depth of well, ...		1500

No rock-salt was found in this well and no gas was encountered in the Niagara limestone. The gas which was found in the Medina sandstone at the depth of 1455 feet showed a pressure of 105 pounds per square inch, after the gas had been confined in the well two hours. The gas when allowed to escape from the pipe, after being confined this length of time, when lighted produced a flame 50 feet in height. According to Mr. H. W. Hatch, the well produces 12,000 cubic feet of gas per day.

A well was drilled for natural gas at Morrisville, Madison County, New York, to the depth of 1889 feet. The altitude of the well-mouth is probably more than 1200 feet above tide.

The well commences in the lower half of the Hamilton and then passes through the Marcellus shale, Corniferous limestone, Oriskany sandstone, Lower Helderberg limestone, limestones, marls, and shales of the Salina, Niagara (?), and ends in the Upper Clinton.

The united thickness of the Corniferous, Oriskany, and Lower Helderberg is 279 feet, of which 186 feet is probably Lower Helderberg. The Salina of this section consists of 325 feet of hydraulic limestone, 590 feet of shales, impure limestone and marls, closing with 225 feet of red shale. Total thickness of Salina, 1140 feet. At 1805 feet a blue argillaceous shale was encountered which may be Niagara.

Gas was obtained at 578 feet and in smaller amount at 755 feet, but not in quantity enough to be of economic value. A stratum of rock-salt, 10–12 feet thick, was reached at 1259 feet in the upper part of red and green variegated marl. Samples from 1805 and 1815 feet show traces of salt.

One of the most common questions asked is, "How deep shall we have to drill in order to reach a certain geological formation?" For all northwestern New York the formation about which the inquiry is generally made is the Trenton limestone. Sufficient data are now being rapidly accumulated to enable this question to be answered for most localities. In central and western New York, west of Montgomery, Schoharie, Eastern Delaware and Sullivan counties, the thickness of the formations in general has been underestimated. One instance with which I am very familiar will serve to illustrate this statement. When it was proposed to drill a test-well at Ithaca, a section was published by Professor S. G. Williams which indicated that the top of the Trenton limestone would be reached at Ithaca at a depth of 2300 feet, and which stated that the bottom of the same formation would certainly be reached at a

depth of 2800 feet. The least depth at which the Trenton limestone would be reached was estimated by Professor H. S. Williams to be about 3000 feet. The Ithaca well is now 3130 feet deep and has just reached the red shale which forms the lower part of the Salina. From the records of other wells which have been drilled to the north of Ithaca, it would not seem unreasonable to conclude that the top of the Trenton limestone cannot be reached in the Ithaca well at a depth of less than 5500 feet.*

Explorations for Gas in Albany County.

The Knowersville well is located about a quarter of a mile south of Knowersville station, on the railroad of the Delaware and Hudson Canal Company, in Guilderland township, Albany county, seventeen miles from Albany. The elevation of the well is 510 feet above tide. Drilling was commenced in strata 595 feet vertically below the base of the Lower Helderberg limestone, which formation rests immediately on top of the Hudson River shales. The stratigraphical position of the top of this well is a matter of great geological significance, since it establishes the true relationship between the base of the Devonian and the top of the Lower Silurian in the Catskill region. The upper part (595 feet) of the Hudson River formation outcrops between the well and the lowest outcrop of the Lower Helderberg limestone beds near the summit of the ridge, about one mile from the well. The Upper Hudson formation constitutes the base rocks of the Helderberg hills which range through Guilderland and Knox townships in Greene County.

No systematic collection of the specimens of the drilling in this well from the surface to a depth of 2500 feet was kept, but it is reported that the strata passed through were composed of gray shales and gray and black alternating slates, which in places were quite calcareous and contained occasional thin sandstones. The drilling of the well was commenced June 26th, 1886. The surface-water was cased off at a depth of 117 feet, and at 497 feet the "*gas-vein*" was struck, which is still producing gas under an undiminished confined pressure of 40 pounds per square inch. No other indication of gas was obtained in this well. A sample of this gas was collected July 19th, 1886, by Mr. J. M. Sherrerd, chemist of the Troy Steel and Iron Company. This sample was afterwards analyzed by

* Professor Prosser stands responsible for all the facts contained in his notes which end here. The arrangement and form of these notes I have materially changed in accordance with Prof. Prosser's request.

Dr. William P. Mason of Rensselaer Institute, with the following results:

Illuminants,	0.3
Carbonic acid,	0.0
Carbonic oxide,	0.0
Oxygen,	2.1
Marsh gas,	59.4
Hydrogen,	11.3
Nitrogen,	26.9
Total,	100.00

The percentage of nitrogen in the above gas is greater than is usually found in natural gas.

The gas-sand was only 6 inches thick, and at a point 50 feet above the gas-sand a pocket of gas was struck which was quickly exhausted. Great difficulty was experienced in getting sufficient water at this well for drilling purposes. In consequence a water-well was drilled to a depth of 325 feet, three feet from the deeper well. No water was got, however, in this second well, but at a depth of 200 feet a pocket of gas was struck. This gas burned to a height of 3 or 4 feet for 24 hours after having been struck, when it became exhausted. The original intention was to drill this well to a depth of 2000 feet, since it had been reported by an official of the Geological Survey of the State that the Hudson River shale formation, including both Hudson River shales and Utica slates, ranged only from 1800 to 2100 feet thick. Taking the maximum estimate as a basis for a computation, the top of the Trenton limestone should have been struck at a depth of 1500 feet.

I was not consulted in regard to this well until after the drill had gone to a depth of 2500 feet without reaching the Trenton limestone. It was then decided to drill the well to a depth of 3000 feet, and in order to ascertain the position of the Trenton limestone in the well, careful samples of all the rocks drilled through were kept, and as the drill progressed careful analyses were made of the drillings so collected. Forty-seven specimens were thus analyzed, with the results shown in the following table.

From the above analyses and also from a careful lithological inspection of the specimens themselves, it was determined that the top of the Trenton limestone was struck at a depth of 2880 feet. The drill passed through 132 feet of the Trenton limestone, the total thickness of which I have estimated to be 500 feet; but no gas was obtained in the well below a depth of 497 feet.

Samples and Analyses from the Knowersville Well.

Depth in feet from which specimens were taken.		Number of Specimens Taken.	Average Analysis.		
From	To		Calcium Carbonate.	Magnesium Carbonate.	Total.
2500	2570	6	21.16	3.69	24 85
2570	2635	4	24.34	3.49	27.83
2635	2725	4	21.79	3.93	25.72
2725	2790	2	33.21	3.11	36.32
2790	2830	3	5.96	5.23	11.19
2830	2880	4	6.52	5.23	11.75
2880	2885	1	46.96	3.36	50.32
2885	2940	5	78.75	3.36	82.11
2940	2965	4	77.50	8.69	86.19
2965	2995	6	58.39	25.49	83.88
2995	3006	3	51.96	33.45	85.41
3006	3012	2	47.76	29.96	77.72
Dark gray calcareous shale, taken at 1682 feet.....			3.63	3.82	7.45
Light gray argillaceous limestone, taken at 2230 feet.....			38.48	4.81	43.29

The geological structure of the rocks in which the Knowersville gas was obtained is such as to make it possible for them to contain gas in larger quantities than in the Knowersville well, although the fact as to whether they do or do not contain gas in greater quantity must be determined by actual drilling. The exceptional pressure of the gas which comes from the Knowersville gas-sand, which is only 6 inches thick, and the constancy in the pressure for the past 18 months, would make it probable that, if this gas-sand can be found of greater thickness elsewhere, it may contain gas in larger quantities than in this well. In order to determine whether this gas-sand was thicker elsewhere and contained commercial gas, a well was drilled on the Finch farm, in Knox township, $4\frac{1}{2}$ miles north 8 degrees west from the Knowersville well.

The elevation of the top of the Knox well is 1155 feet above tide, or 645 feet above the top of the Knowersville well. The elevation of the top of the Hudson River shales and slates, at a spring about one-eighth of a mile from this well, where the Lower Helderberg limestone is seen to lie directly on top of the Hudson River shale, is 1235 feet. The average dip per mile from the Knox well to the Knowersville well is 40 feet. Between these two wells, however, there are a number of local dips, which would not materially affect the general position of the rocks, as indicated by the average dip given.

The geological horizon of the Knowersville gas-sand was passed through in the Knox well at a depth somewhere between 1000 and 1050 feet, but no gas was found. Drilling was stopped in this well at the depth of 2200 feet, or 1200 feet above the top of the Trenton limestone. Carefully selected specimens of the strata passed through in the Knox well were kept; and all the specimens from the top to the bottom of the well have such a similar character that it is impossible to define any marked change in the lithological characteristics of the rocks, which are composed of gray shales and gray and black slates, quite calcareous in places, and containing, scattered throughout the entire depth of the hole, a number of thin argillaceous sandstones. No chemical analysis was made of the specimens taken from this well and no indication of gas was obtained in it.

Geological Section of the Catskill Mountain Region.

In order to construct a complete geological column of the Palæozoic strata from the top of the Catskill mountains to the bottom of the Mohawk Valley I made numerous measurements, the details of which would be too extended to publish in this place. The following is a general section:

Carboniferous.	No. X.	Pocono or White Catskill sandstone and conglomerate,		1000
Devonian.	No. IX.	Catskill red sandstone and shale,		2900
	No. VIII.	Chemung sandstone and shale,		1130
		Portage shale and sandstones,		1315
		Genesee shales and slates and Hamilton flags, sandstones and limestones,		1075
		Marcellus shales and slates,		900
		Upper Helderberg:		
		Corniferous limestone,	60	85
		Onondaga limestone,	20	
		Schoharie limestone,	5	
		Caudagalli grit,		40
	No. VII.	Oriskany sandstone,		10
	No. VI.	Lower Helderberg (and waterline),		200
		Salina, Niagara,		wanting.
	No. V.	Clinton,		"
	No. IV.	Medina and Oneida,		"
	No. III.	Hudson River shales, slates and sandstones,		3500
	No. II.	Trenton limestone,*		500
		Total thickness of section,		12655

* One hundred and thirty-two feet of the Trenton was actually pierced by the Knowersville well. No section was measured of the strata below the Trenton.

The above section represents the aggregate thickness of the strata which might be expected to be found if a well should be drilled to a depth of 13,000 feet, commencing on the highest summits of Shandakin township, in Greene County, where some of the highest mountains of the Catskill group are contained.

The geological structure of the Hudson River Valley east of the Catskill Mountains is extremely complicated, the principal Silurian strata being thrown into numerous anticlinals and synclinals, along the slopes of which they have varying dips west of the extreme western outcrop of the Upper Helderberg limestone. Along the foot-hills the geological structure is extremely simple, consisting of monoclinal ridges and valleys in which the rocks are all found dipping to the west and northwest. The most western outcrop of the Upper Helderberg limestone has a dip in many places as high as 65 degrees. This dip declines, rapidly at first, and afterwards gradually, toward the west to a point between Lexington and Prattsville, where the rocks lie comparatively horizontal. West of Prattsville the strata dip slightly to the east and southeast.

From these dips it is evident that the rocks forming the Catskill Mountains lie in a basin with its center in a northeast and southwest line in the vicinity of Lexington and Prattsville.

From the dips to be observed along the Ulster and Delaware railroad, it would appear that this basin declines toward the southwest. They are probably only local rolls or small basins in the slopes of the main basin.

Explorations for Gas in Greene County.

The Cairo well is located in the northern part of district No 5, Cairo township, Greene County, 3½ miles in an air-line southwest of the village of Cairo, and 610 feet above tide. Black Mountain, the top of which is 3975 feet above tide, lies immediately above and to the west of the well. This well was located in the spring of 1886 by practical oil-operators from the Pennsylvania oil-regions, under the belief that the Trenton limestone would be struck at about 1150 feet, or the same depth at which it was expected to strike the top of the Trenton limestone in the well drilled at Knowersville in Albany County. As a matter of fact, however, my geological examination, made in the fall of the same year, proved that the Cairo well would have had to be drilled at least 5300 feet before the drill would have encountered the Hudson River sandstone, in which the drilling of the Knowersville well was commenced. The drilling of the Cairo

well was stopped in November, 1886, at a depth of 2200 feet. The following is a record of the well:

Well-mouth above ocean in feet,		=	956
1. Soil,	4 to 4 =		951
2. Gray flagstone,	3 to 7 =		948
3. Red sandstone,	30 to 37 =		918
4. Red and greenish gray shale,	23 to 60 =		895
5. Bluish gray sandstone,	40 to 100 =		845
6. Green shale,	30 to 130 =		815
7. Red argillaceous sandstone,	5 to 135 =		810
8. Gray flaggy sandstone,	20 to 155 =		790
9. Red sandy shale,	30 to 185 =		760
10. Gray sandstone,	15 to 200 =		745
11. Bluish gray slate,	25 to 225 =		720
12. Red shale,	30 to 255 =		690
13. Gray sandstone,	75 to 330 =		615
14. Red sandstone,	110 to 440 =		505
15. Bluish gray slate,	35 to 475 =		470
16. Red sandstone,	65 to 540 =		405
17. Gray sandstone,	70 to 610 =		335
18. Gray flaggy sandstone,	15 to 625 =		320
19. Dark gray sandstone, very arenaceous,	125 to 750 =		195
20. Red sandstone,	35 to 785 =		160
21. Gray sandstone,	25 to 810 =		135
22. Greenish gray shale,	5 to 815 =	+	130
23. Red shaly sandstone,	305 to 1120 =	—	175
24. Red and gray slate, alternating,	10 to 1130 =	—	185
25. Gray and white shale alternating,	90 to 1220 =	—	275
26. Red shaly sandstone,	55 to 1275 =	—	330
27. Gray slate,	25 to 1300 =	—	355
28. Soft red sandstone,	150 to 1450 =	—	505
29. Gray sandstone,	140 to 1590 =	—	645
30. Very hard gray sandstone,	20 to 1610 =	—	665
31. Dark gray sandstone,	90 to 1700 =	—	755
32. Hard white sandstone,	20 to 1720 =	—	775
33. Red and gray shale alternating,	70 to 1790 =	—	845
34. Gray shale and sandstone alternating,	150 to 1940 =	—	995
35. Gray sandstone and shale, with thin and scattered alternating beds of red and green shale,	260 to 2200 =	—	1255

The last fresh-water vein encountered in this well was struck at 390 feet. This water was shut off by a casing set at 402 feet. A salt-water vein was struck at 610 feet. This water was subsequently shut off by a $5\frac{5}{8}$ inch casing set at 621 feet. The amount of salt water obtained at the depth of 610 feet filled the well to a height of 300 feet in 26 hours.

The rocks cut by the drill in this well were very much harder

than those ordinarily encountered by the drill in the northern part of the Pennsylvania oil-regions, where many wells start at the base of the Olean conglomerate or the bottom member of the Millstone grit, No. XII. In a general way, the hardest strata were encountered above the point at which the salt water was found. The hardest stratum passed through in the well was the gray sandstone lying between 1590 and 1610 feet. This sandstone bed was so hard that the drillers reported it to be granite. Great difficulty was encountered in drilling the lower part of the well, which was finally abandoned, on account of the tools being lost.

It is interesting to note that the flaggy sandstone which outcrops on the turnpike, one mile southeast of Cairo, lies near the top of the Portage formation. The sandstone has a dip $3\frac{1}{2}°$ north, 45° west, and its surface is covered with bold glacial scratches having a direction south 10° west. This stratum was struck in the Cairo well between 1130 and 1220 feet.

What was taken to be the junction between the Portage and Hamilton formations occurs along the turnpike, where it crosses the line separating Catskill and Cairo townships. The bottom of the Hamilton formation outcrops in the vicinity of school-house No. 18, about a mile from Leeds.

The dip of the strata in the vicinity of the Cairo well precludes the existence of natural gas in commercial quantities. In the vicinity of the well the strata dip north 67° west, 185 feet to the mile. This is the minimum dip in this part of Greene County. The dip of the Corniferous limestone, where it outcrops at the town of Leeds, along the Catskill creek, is 1120 feet to the mile; the average dip from this outcrop at Leeds to the Cairo well is 580 feet to the mile.

Although gas in commercial quantities may be found in eastern New York, I have no hesitancy in asserting that it cannot be found in the region between Kingston, Catskill village and the Cairo well.

Scattered Explorations for Gas.

A number of exploration-wells have been drilled in various parts of the State. The following are scattered notes in my possession relating to some of these wells:

A natural-gas flow was struck in a well at Rodman in Jefferson County, September 4th, 1886. It is reported that this gas was found at a depth of 162 feet in a "seam of slate," limestone having been drilled through from the top of the well to a depth of 160 feet.

This limestone is evidently the upper portion of the Trenton formation.

In a well drilled at Norwich, Chenango County, which had gone to a depth of 900 feet in September, 1887, it was reported that a small show of gas was obtained in the Upper Hamilton. The elevation of the railroad station at Norwich is 1001 feet above tide.

A well is about to be drilled in Broome County, near the borders of Chenango, to a depth of 2000 feet.

A well was drilled to the depth of 1400 feet in the Neversink Valley, near the borders of Orange and Sullivan, which cost abont $15,000. No indications of gas were met with and the well was abandoned.

In the town of Barker, in the Chenango Valley, a well has been drilled to a depth of 2175 feet, at a cost of $10,000. Indications are said to have been found in this well of the existence of salt, oil and gas.

At Uniontown, in Madison County, a well has been drilled which got a small amonnt of gas from the Lower Helderberg limestone.

At Brockport and Gasport, wells are reported to have been drilled down to the Trenton limestone.

At Fulton, in Oswego County, a well has recently been drilled to a depth of 1727 feet. The elevation of the railroad station at Fulton is 387 feet above tide. This well commenced drilling in the Medina sandstone. The following is a section of the well:

IV.	Medina Sandstone,	400 feet.
III.	Hudson River shale,	880 "
	Utica shale and slate,	120 "
Trenton limestone,		327 "
Total,		1727 "

Mr. J. H. Case, of Fulton, reports that a small showing of gas was struck at the following depths: 42, 80, 325, 520, 585, 700, 844, 990, and 1665 feet, respectively.

At 1727 feet, 327 feet below the top of the Trenton limestone, gas was struck in such force as to throw sand from the well to the top of the derrick, a height of 74 feet 10 inches. The gas caught on fire and the derrick was burned down. This occurred during the first week of January, 1888, and for eight days after the gas was struck it burned to a height of about 2 feet.

At New York Mills, three miles west of Utica, a well has been

drilled, about which Professor Charles D. Wolcott reports the following facts:

"It started about 60 feet below the Oneida conglomerate and was drilled about 800 feet, passing through the Hudson and Utica shales to the Trenton limestone, and then 790 feet to what may be the Potsdam sandstone. At 2000 feet the drill entered the Gneiss. Gas was found about 500 feet down in the shales. I was not on the ground, but depended upon the owner of the well for samples of the rock and the record of the drilling." The elevation of the Erie canal at Utica is 428 feet above tide.

Mr. De Puy, of Bath, N. Y., reports the following facts:

1882. On Smith lot, half-mile south of Bath village. Depth, 2050 feet. No record kept of depth of different strata. Gas found in very small quantity—"enough to burn about two hours." Reported find of oil in small quantity, but believed to be a hoax.

1886. On James Wagner farm, half-mile west of Howard village, Steuben County. Depth, 2000 feet. No records kept as far as I can learn. No oil; no gas, except in very small quantities.

1866 or 1867. A well was sunk by oil-prospectors near Campbelltown, Steuben County. I have been able to learn nothing in regard to it except that no oil was found.

Near Cohocton, Steuben County, a well was drilled for oil, but I have not been able to see any one who could give me any definite information about it.

At Penn Yan, in Yates County, in the latter part of 1887, a well was drilled by Mr. William Townsend. Sufficient gas was obtained from this well to heat and light Mr. Townsend's house for several weeks after it was struck. It is reported, however, that the yield of the well failed a few weeks after the gas was struck.